CARLOW

DETERMINING THE BEST WAY TO REPRESENT COMPUTER FUNCTIONS TO THE USER: TEXT ONLY, GRAPHICS ONLY, OR A MIXTURE OF BOTH

March 1988

DAAA15-86-D-0005

Carlow Associates Incorporated
8315 Lee Highway, Suite 410
Fairfax, Virginia 22031
(703) 698-6225

Executive Summary

Background.

Recent advances in computer technology have provided designers with a wide range of alternatives for representing system functions to users. These alternatives range from short command abbreviations to complex english-like statements to graphic symbols. As a result, there has been a proliferation of terminology and interaction modes leading to extreme non-standardization of the user-computer interface. This condition is of particular concern for the Army in that standardization is a necessary prerequisite for minimizing training time and costs, and ensuring inter-system compatibility.

Recognizing the potential impact of this situation on system readiness, a research program was initiated to assess the magnitude of the non-standardization problem and to identify trends in the assignment of names, abbreviations, and symbols. As part of that effort, a pilot study was conducted to determine the requirements for conducting a major study to evaluate the relative effectiveness of alternative modes of function representation. Three modes of representation were selected for the pilot study: text only, graphic only, and mixed (text and graphic). This report presents the results of the pilot study.

Methodology.

Relevant literature was reviewed to identify appropriate independent and dependent measures and similar methodological and analytical considerations. In order to ensure that comparisons of the alternative representation modes would be meaningful, it was first necessary to develop algorithms for generating functionally comparable command sets. These algorithms consisted of production rules for defining the relative amount of information to be contained in each representation. Two sets of production rules were developed, and applied to a set of standard text editing functions to create alternative command sets. These command sets served as the principal stimuli during the study. Text editing was selected as the task for the pilot study based on three factors: 1) presence of clearly defined functions, 2) existence of accepted command terminology, and 3) ready availability of subjects with varying levels of experience.

The experimental procedure consisted of five tasks conducted in two separate session. Session 1 consisted of a practice task, an acquisition task, and a primary recall task. Session 2 consisted of a secondary recall task, and a rating task. The independent variables used were: 1) text editing experience, 2) presentation format, 3) representation production rules and 4) experimental session. Thirty (30) subjects were matched by age and sex within the three experimental categories (ten each). The dependant variables were: 1) acquisition time, 2) primary and secondary recall response times; and 3) primary and secondary recall response errors. Preference ratings were used to assess the strength of relationships between stated preference for the various representation modes and actual performance with each mode.

The response measures were evaluated via a series of ANOVAs (five (5) three-way, and two (2) four-way). Three-way (experience, format and setblock) ANOVAs were performed for the acquisition, primary, and secondary recall response time dependent measures. Similarly, three-way ANOVAs were performed on primary and secondary recall response errors, using average percent correct as the actual measure. Additionally, two four-way ANOVAs were performed on combined response time and error data (adding sessions as the fourth independent variable). Where appropriate, the ANOVA findings were analyzed using the Newman-Keuls multiple comparisons testing procedure to determine the exact nature of significance.

Results.

A priori hypotheses predicted that experience would significantly influence acquisition, primary and secondary recall response times, as well as the number of primary and secondary recall response errors; however, evidence of this effect was not forthcoming.

The main effect of format achieved significance at the .01 level for all dependant measures. Of particular interest was the relative difference between iconic and textual representations. The findings indicate that on the average, subjects required longer to recall iconic representations than either the text or mixed formats, and that on the average, subjects made errors more frequently when evaluating icon representations than either text or mixed representations of the same text editing functions.

The main effect of setblock achieved significance at the .01 level for all dependent measures with the single exception of the acquisition time measure. Findings indicate that set 2 (text and mixed) required significantly less time to provide a response, and that set 2 stimuli were correctly identified significantly more frequently.

The two-way interaction of experience and setblock achieved significance at the .01 level for primary and secondary recall response errors; and .05 level of significance for the four-way ANOVA average percent correct responses. Analyses indicate that the significant differences in response errors was primarily between the low experience subjects when compared to the medium and high experience subjects (few significant differences were obtained between the medium and high experience groups).

The two-way interaction of format and setblock achieved significance at the .01 level for all dependant measures.

Finally, the three-way format by setblock by session interaction achieved significance at the .05 level using response time as a dependent measure.

Conclusions.

The results of the pilot study indicate that there are significant differences in terms of both recall time and errors for alternative modes of representing command functions. However, artifacts of the experimental design make definitive interpretation of the results problematic. In the present study, subjects were instructed to learn and/or recall specific designations, as opposed to the meaning of a representation. Therefore, a response was evaluated as incorrect if the designation and response did not match exactly. Different results would be expected if subjects were requested to learn and recall a meaning of a specific representation (semantics), as opposed to a specific term or designation (lexicon). The primary rationale for this hypothesis rests on the strong relationship that exists between the text format condition and the designation as defined in the study. Structuring the tasks so that semantic relationship between a representation and the corresponding function is examined would provide a clearer indication the relative merits of the presentation formats.

LIST OF TABLES

LIST OF FIGURES

Introduction

Background

In spite of the widespread development and implementation of icons in user-computer interfaces, there are several unresolved issues concerning their adequacy. Other than temporary changes due to the novelty of this approach, what can be expected with respect to performance of the end-user? More succinctly, how does the iconic interface compare with command strings (textual representations) in terms of: skill acquisition, intelligibility, ambiguity, recognition, reaction time, recall, preference?

With few exceptions, the scientific community has not committed itself to addressing these issues. In contrast, the popular literature is overwhelmingly in favor of this concept, as evidenced by the popularity of the computer systems that support such interfaces.

The application of iconic interfaces can be classified into three categories, in order of increasing user involvement: operating systems, end-user application programs, and programming languages.

Operating Systems

Operating systems such as those for the Xerox Star, Apple Lisa and Macintosh, prompt users for inputs through the use of icons. Elements of an operating system can be represented by the following icons: file folders, documents, disks, trash cans and a "desktop". While these implementations are not purely iconic (they are supplemented by pull down or popup menus), they do isolate the user from complex command sets and syntax-based procedures. The user can manipulate an object on the desktop by utilizing a "mouse" or similar input device. For example, to delete a file, the operator opens the appropriate folder, identifies the particular document, selects the document, and drags it over the trash can. Until such time as the trash is explicitly emptied, the operator can recover documents that have been thrown away.

Transactional metaphors such as these may seem to trivialize the work they represent, but in fact they strengthen the relationships between the operator and operations (Dreyfus, 1966; Lee and Lochovsky, 1966).

End-User Applications

End-user applications vary in the degree to which iconic interfaces are utilized. For example, graphics programs (i.e., MacPaint, MacDraw, and MacDraft) tend to rely more heavily on pure iconic interfaces than do word processing and spreadsheet applications. One Macintosh database application, Helix by Odesta relies almost exclusively on an iconic interface, providing a graphic representation for almost all the required functions. In fact, a user can specify all data structures, relationships, and formats without utilizing supplemental pop-up menus. With the exception of labeling the data form, the user only interacts with icons.

Programming Languages

The closest approximation to a pure iconic interface may be found in computer programming. Considerable effort has been expended developing means for programming via symbolic constructs. While the concept has recently made a dramatic resurgence, the ground work for such systems has its roots in projects that span the last two decades. As reviewed by Glinert (1985), specific examples include work done by I. Sutherland, W. Sutherland, Smith, Ellis, Christensen, and Finzer.

Ivan Sutherland developed the first graphical application program (cited in Glinert, 1985). The program was developed to assist people in visualizing concepts. The program utilized multiple windowing features and used a light pen as an input device.

In a similar effort, William Sutherland developed a metaphorical system (cited in Glinert, 1985). In this system, program elements were arranged much as an electrician would design an electrical circuit.

Smith's work (cited in Glinert, 1985) at the Stanford Artificial Intelligence Laboratory focused on the development of PYGMALION, a graphical programming environment. Smith's work evolved in part out of efforts by Sussman in programming by example. Succinct reviews of other significant iconic programming systems are detailed in Glinert (1985) and include: GRAIL; AMBIT; and Programming by Rehearsal (Finzer & Gould,1984).

Assuming the iconic interface possesses potential as an effective interface medium, the iconic interface needs to be defined in terms of its salient characteristics. Specifically, the features that determine the effectiveness of the icon as a graphic interface need to be identified, operationally defined, and investigated. Related work in symbolic interaction suggests that context, experience, stereotypical expectation, age, and sex can play a critical role in determining the success of the symbolic interface. Research findings for these variables are presented in greater detail under the appropriate heading in the literature review.

Literature Review

The literature supporting this study comes from three general areas of research: the design and evaluation of symbols for use in international trade, safety, and automotive applications; the design and evaluation of human-computer interfaces; and research on word processing applications.

Considerable research has been directed at the specification of the critical characteristics of symbolic representations in traffic & automotive applications (Allen, Parseghian & Van Valkenburg, 1980; Brainard, Campbell & Elkin, 1961; Dewar & Ells, 1974; Dewar & Ells, 1976a; Dewar & Ells, 1976b; Dewar, Ells, & Mundy 1976; Dewar &

Swanson, 1972; Ells & Dewar, 1979; Green, 1979; Green & Davis, 1976; Green & Pew, 1978; Griffith & Actkinson, 1978; Heard, 1972; Jack, 1972; King, 1971; Smith & Weir, 1978; and Walker, Nicolay & Stearns, 1965). Similarly, research and practical experience have demonstrated the utility of symbolic representations in international trade and safety (Cairney & Sless, 1982; Collins, 1983; Collins & Lerner, 1982; Collins & Pierman, 1979; Dreyfus, 1966; Easterby & Haskiel, 1977; Easterby & Zwaga, 1977; Kolb, 1967; Mackett-Stout & Dewar, 1981; and Ursic, 1984).

Several efforts have focused on evaluation of iconic interfaces for computer systems and related applications (Bewley, Roberts, Schroit & Verplank, 1983; Brown, Carling, Kramlich & Souza, 1985; Brown & Sedgewick, 1984; Clark & Robinson, 1983; Glinert, & Tanimoto, 1984; Glinert, 1985; Hemenway, 1982; Lodding, 1983; Melamed & Morris, 1985; Rogers, 1986; Shu, 1985; Smith, Irby, Kimball, Verplank & Harslem, 1982; and Smith, 1975), but very little research has been directed at identifying the utility of the icon as an interfaces medium for the most prevalent computer application, word processing.

Word Processing

As related by Roberts and Moran (1983):

> Text editors are the most heavily used programs on interactive computing systems since the advent of time sharing systems (Boies, 1974). Text editing, or word processing is also a very pervasive use of personal computers (The Seybold Report on Word Processing; April, 1981). There are probably hundreds of different text editors in use today: many computation centers have their own local editors, and new computers often come with their own text editors. System programmers cannot seem to resist the temptation to design a better text editor. Heated debates rage over computer networks about text editor design. Yet, remarkably little objective information is known about the relative advantages of different kinds of editing paradigms.

While the authors are referring to text editors, the same can be said for the different iconic paradigms.

As detailed by Rohr and Keppel (1984), the major benefit of the symbolic interface within word processing may be that graphic representations map more directly to real world events than do textual representations of the same events. As related by Rohr and Keppel (1984),

> The use of iconic interfaces in place of verbal command sets has been discussed recently. The basic idea why iconic interfaces is: (sic) icons can be constructed in such a way that the user has a better chance to acquire implicitly a model of system structure when looking at the whole set of icons than when he would have dealing with a verbal command set. This assumption is based on the fact that there exist special areas of information presentation where complex information could be presented more condensed and in a wholistic way by graphical symbols.

Contrary to their proposed hypothesis, Rohr and Keppel (1984), demonstrated no significant difference between the particular icon set utilized and verbal command performance when evaluating totals on "task time" and "faults per operation". However, they did find a statistically significant difference between number of times subjects requested assistance from an on-line help utility. Specifically, the verbal command group requested a greater number of requests for "general help" than the icon group. This may indicate that general instructions can be adequately depicted by icons.

Conversely, the icon group requested help more frequently for file-handling symbols. The authors provide the following explanation:

> the verbal command group had more difficulties to acquire an adequate mental model of the system structure than the icon groups, but has an easier understanding of the single commands in the file handling state. Verbal nouns can better represent concepts of processes like print, rename, etc. For editing functions this advantage of verbal commands is lost.

The quality and composition of the command sets or the command set implementations may also provide an explanation for these results. By replicating their approach with different text and icon command sets, one could test the robustness of these findings.

Acquisition

Douglas and Moran (1983), present a cognitive model that suggests that naive users learn text editor semantics by analogy:

> The learner is trying to acquire the cognitive skill required for (presumably) expert use of a text editor. Text editing skill can be represented as a *problem space* (Card, Moran, & Newell, 1983, Ch. 11). The initial learning task is to build such a problem space. This is done incrementally, not by some sort of pure induction, but rather by borrowing skills from other related domains, which we also consider to be represented as problem spaces. The hardest aspect of **learning** (emphasis added) the problem spaces associated with computer systems is in understanding the operators (i.e., commands). The *operator semantics*, the detailed specifications of how the operators affect the system's conceptual entities, is intricate in computer systems. Thus, the difficulties with the learner's rough initial problem space of editing is due to incorrect knowledge of operator semantics. What the learner does is borrow operators from the typewriter space and apply them in the editing space, which causes unexpected results.
>
> As Halasz and Moran (1982) and Gentner (1983) have pointed out, the problem with using analogy as a teaching device is the inability of learners to distinguish the differences from the similarities, that is, novices tend to over extend similarities, thus causing misconceptions. There are two sources of misconceptions when using one operator for another: (1) unknown preconditions and (2) unknown postconditions...these subtle differences are what makes it difficult to learn by analogy.

If this model and implicit assumptions are valid, then improvements in mapping between problem domains would be reflected in measures of performance. That is, if the experience with a device can be translated across systems, the same should be true of conceptual representations of events or actions. If experience with a symbolic representation accurately maps with the real world event, then previous exposure to that representation should improve performance more than a textual representation of the same function. Due to a heavier reliance on analogous situations, effects should be more dramatic for inexperienced users than for their experienced counterparts.

Symbol vs. Text

Words appear to have less ambiguous meanings than pictures (Hartman, 1961), are usually considered essential for representing abstract concepts (Gibson, 1954), and are regarded by developmental psychologists as important tools in forming logical operations in thinking (Piaget, 1969).

In developing and evaluating the Star Workstation interface (Xerox 8010), considerable effort was directed at the identification and utilization of the most efficient set of icons. However:

> These tests did not consider the issues of whether iconic representation and implicit commands are better than typed names and typed commands or whether a small set of "universal" commands (Delete, Move, Copy, Show Properties) applied uniformly across domains (text, graphics, printing, mailing) are superior to a large number of commands specialized to each domain." (Bewley, Roberts, Schroit, and Verplank, 1983).

It would appear that extensive research has been motivated on the assumption that the iconic representation of command structures enhances user performance when compared with textual counterparts. With the exception of work reported in Rohr and Keppel (1984), the only empirical evidence of this nature has been in traffic and automotive design research, hardly direct corollaries to human-computer interface studies.

Symbols

As evidenced by the rebus methodology of reading instruction, individuals often learn to read text only after experiencing an object visually. The association between a visual representation and the corresponding object is followed by an association between the picture and its textual representation.

Without some prior knowledge, learning or acquisition of a reference set usually does not occur successfully on the first pairing. The process is typically iterated over time and across situations before becoming an integral part of an individual's reading repertoire. For this reason, it is hypothesized that a parallel process may hold in the recall of symbols representing word processing functions. There may be a differential experience effect whereby the more pairings between a referent and an object, the more established a specific meaning or association becomes.

Kolers (1969), provides a rather succinct historical narrative on the evolution of several writing systems. Additionally, he elaborates on the advantages and disadvantages of these systems. In particular, he identifies the following characteristics associated with pictorial writing systems.

> The mechanism for reading pictures requires that the reader be able to abstract from his experience with the real object some relation of its distinguishing marks and to generalize the relation to the picture itself (*cf* construct experience). Consequently, the pictorial representation need not be as accurate or detailed as a photograph because human memory is not photographic. As Ryan and Schwartz showed, caricatures that emphasize the distinguishing features make for easier recognition than photographs do.
>
> The mechanism of action of phonetic writing is of course the concatenation of individual graphemes. The graphemes themselves are arbitrary marks; even the basis of their shape is in dispute, some historians arguing for a derivation from pictorial representations and others arguing for unique invention (Diringer, 1968; Gelb, 1963). But having mastered the grapheme-phoneme the person unfamiliar with the correct written form of a word can nevertheless write it so that its phonetic structure can be recovered, as witness the many instances of illiterate or childish spelling that are readable. In effect, then, mastering a small set of arbitrary symbols permits the person to represent all of the words in his language. It allows him, furthermore, to represent many other languages as well and to pronounce their written form. He could do this even though he had spent all of his life in a windowless room whose only content was print or even if having been born blind, his grapheme-phoneme was based on Braille. A person raised in a windowless room could never read pictograms.

Kolers further speculates, that "the success of the drawing depends on the experience of its reader and his ability to infer the object from the parts shown." This ability is partially a function of the individual's cognitive development, and partially a function of the mapping of the representation to the concept. With respect to a particular application, the distinction between an abstract and a pictographic representation of a concept becomes a practical rather than a philosophical consideration.

Insights into the potential of symbolic writing systems are provided by Kolers (1969).

> Pictorial representations are sometimes thought to have a "universality" about them that transcends the limitations on writing imposed by a phonetic

> (alphabetic) system.... Picture writing is even sometimes referred to as "Instant Language" and the hopes are quite high for its use.

A primary assumption in the utilization of symbols is that what the symbol is purported to represent must be in an individual's vocabulary. That is not to suggest that an individual's vocabulary is static or that it cannot be modified in terms of its breadth or scope, but rather that the meaning associated with a particular concept or structure must be available to the individual at the appropriate time. To elaborate, an individual may be able to correctly identify the intended meaning of an icon at one time, but due to mechanisms such as retroactive interference, the concept representation-association pairing erodes or is replaced by a pairing with a different associative meaning.

Caron, Jamieson and Dewar (1980) present the following important aspect of interface design:

> Present evaluation techniques based on how 'accurately' observers label or name pictographs are unable to discriminate between at least some members of the final set of pictographs. As a consequence, nonarbitrary selection of the best pictograph is usually based on 'preference' measures. However, such preference ratings are demonstrably inadequate: first, they do not provide a valid index of sign meaning (cf. Dewar and Ells, 1974), and second, uncontrollable extraneous variables have major effects on such judgments. As an example of the latter, Zajonc (1968) has demonstrated the great extent to which preference judgments merely reflect familiarity with the stimuli.

These criticisms are not unique to iconic representations as evidenced by the existence of multiple commands for a given function (Table 1). A distinct but related view is maintained by Rosenberg (1983):

> Within the domain of either names or actions, distinctiveness is the salient aspect: lack of distinctiveness among the names or actions gives rise to confusability. Between the domains of names and actions, similarity is the salient aspect: the more similar the features of a name and an action, the more likely name is to be a "good" name (in suggestiveness, memorability, etc.). At a minimum, an "ideal" system would have a set of actions which were distinctive, so as not to be easily confused, and a set of names whose features were highly similar to those of the actions, so as to be suggestive and serve as good cues for learning and remembering the actions. Note that if these two conditions are met, it follows that the names would also be distinctive, since their structure would mirror that of the actions.

Performance

Symbolic representation of traffic control concepts have been demonstrated to be more accurately and more rapidly recognized than written text messages (Ells and Dewar, 1979), can be easier to learn (Walker Nicolay and Stearns, 1965), and be retained with essentially complete recall. In contrast to these findings, Stern (1984) reports that "graphic instructions" to subjects attempting to perform monetary transactions via an automated teller machine (ATM) were not as effective as pure textual or combined text and graphics. Subjects presented with graphic procedural instructions and error messages took approximately two times as long to complete the first transaction and made almost three times as many errors as those who were presented with either pure textual or the combined text and graphic forms.

In research comparing symbolic representation of instructions to printed instructions, Booher (1975) found a significant difference for response times and task performance. Booher determined that the pictorial group (subjects utilizing instructions rated high in pictorial coding) demonstrated shorter response times. But, this same group was also responsible for the largest number of errors. However, when the pictures were supplemented with printed instructions, the combined group (picture and printed instructions presented together) achieved the highest performance measures. In attempting to explain the time differential, Booher presents conclusions of Haber (1970):

> information-processing mechanisms we use in the memory of pictures and faces are stored almost directly as images, while the storage of words requires an additional coding process. This suggests that instructions presented pictorially may allow the reader to more readily use those cognitive processes involved in iconic imagery and pictorial perception as an aid to understanding the instruction.

Preference

Stern (1984) reports that text, and combined text and graphic instructions were preferred to synthesized voice instructions. Additionally, subjects "reported that the messages that depicted simple, concrete actions (guidance messages) were easier to understand than the messages that depicted more abstract concepts (error messages)".

There was disparity between preference and performance. This can perhaps be explained by Booher (1975):

> Pictures have been proposed as better than words in communicating information about concrete objects and events (Gibson, 1954, 1966), for presenting stimulus information in associative learning (Bern, 1958; Lumsdaine, 1949), and in reinforcing important cues in classroom instruction (Wicker, 1970). In the search for a universal language, pictures are appealing because of their relative processing ease, the large amount of information which they can convey in a small space, and possible advantages in **long-term** (emphasis added) memory retention.

<u>Accuracy</u>

Walker, Nicolay, and Stearns (1965), demonstrated that "symbols can be recognized significantly more accurately than word signs." Additionally, the author's report that a memory test conducted 24 hours after the initial learning trials indicate that subjects were able to perfectly recall symbol signs and their meaning. These results (comparing the accuracy of American and international road signs) were achieved in spite of several biases that should logically counter such findings. Specifically:

> (a) familiarity (experience) was a positive factor in favor of the word signs, as all of the Ss had lived in America for at least seventeen years and 77% of them were licensed drivers;
>
> (b) the particular symbols chosen for the experiment have been demonstrated to be the most difficult in the international system for American Ss to learn and interpret (Brainard, Campbell and Elkin, 1961);
>
> (c) in stage one the symbol stimuli were all black instead of the usual red-white or red-white-black, so that color cues would not be a positive factor in discriminating the symbols from the typical American black-word signs.

In evaluating interpretability of road signs, Brainard, Campbell, and Elkin (1961), discuss the characteristics of signs with initially low evaluation scores as compared to those with high scores. The signs with low scores (below 15% correct) were generally those which made use of some abstract coding dimension (e.g., circle and/or slash line to denote a prohibitive action). The signs with high scores (above 85% correct) were characterized (a) by having a direct counterpart in the American road sign system, and/or (b) by being a direct pictorial representation of the sign meaning.

It would appear that the performance deficiency obtained with respect to the signs with low evaluation scores was due in part, to "abstract, unfamiliar symbols or ... ambiguous cues." These deficits, while related to differences between text and print, are also a function of subject experience and stereotypical expectations.

Experience

Experience can be described with regard to two attributes. The first, termed construct experience, refers to the experience required to interpret and utilize symbolic representations of constructs. The second, identified as application experience, relates experience effects as a function of exposure to a specific application (i.e., word processing programs).

Construct Experience. The more experience an individual has with a concept, the better his/her performance with regard to correctly identifying graphical symbols (Cahill, 1975; Brainard, Campbell and Elkin, 1961; Kolers, 1969). Cahill suggests that this advantage may be explained by maintaining that the better defined a concept is, the easier it is to depict and to exploit the poignant aspects graphically. She states that:

> no symbol should be conceived in isolation, for it will not, and cannot be expected to, stand alone. The significance a symbol conveys is embedded in the entire context in which it will be used, which then comes to serve as a kind of generalized '**semantic marker**' (emphasis added) affecting its interpretation.

Kolers (1969), relates similar concerns:

> The reader of the pictures, however, must know what the device is intended for and have some familiarity with the operating characteristics of classes of the device.

He further states:

> Someone for whom shaving is an unknown custom could not be expected to use an electrical razor properly from drawings of its operation; someone who has no knowledge of computers as a class of instrument could not be expected to run one properly from pictures of its control panel.

Brainard Campbell, and Elkin (1961) compared the intelligibility of European to American road signs. They found a significant difference in the number of roadway signs correctly identified after having provided subjects with the "correct sign meanings". Context and experience with a concept are two important variables when developing or evaluating iconic representations.

Application Experience. Text editing performance is usually considered to be positively correlated with experience. That is, more experienced users demonstrate more efficient editing strategies, utilize a more complete set of available commands, require less time to affect a change, and perform a given word processing task more accurately.

Rosson (1983) reports that subjects' experience correlated significantly with the number of different commands utilized (where experience was defined as a composite of self-reported frequency and length data). Similarly, the rate and speed at which commands were entered were significantly correlated with the same measure of experience. This *activity* measure was modified to determine if the degree to which a file was manipulated, increased as a function of experience. The *effect rate*, a ratio of the total number of changes made to the total editing time required, correlated significantly with experience. Evaluation of the activity and dependent measures indicated that not only do more experienced word processors work more quickly, but that they also modify their files more efficiently. Further investigation determined that the "productivity"[1] differential was not due to increased frequency of use of "more powerful commands" by the more experienced users.

[1] "... while there is no guarantee that more rapid change to files is symptomatic of increased productivity (i.e., not all of the changes may be constructive), it is certainly consistent with such a conclusion." (Rosson, 1983).

Stereotypical Expectation. Utilization of stereotypical expectations facilitates the interpretability of symbols. Brainard, Campbell and Elkin (1961) found that signs exploiting stereotypically expected features were correctly identified an average of 75% of the time as compared to 45% for standardized counterparts. However, they also determined that "signs based on stereotypes of only moderate strength (30-40%) will not always be interpretable."

In investigating the relevant characteristics that contribute to establishing stereotypes, Howell and Fuchs (1968), indicate that (with respect to their particular application), there exists three basic attributes of graphical symbols. Specifically, these factors are: *population stereotype* (or specific meaningfulness factor), m*eaning and familiarity* attribute and a *pictorial quality and complexity* factor. Detailing the subtle differences between the attributes, the authors conclude:

> it appears that stereotypy or *specific* meaningfulness is distinguishable from *general* meaningfulness or association value. Whereas the former is hypothesized to be a beneficial coding variable, the latter could conceivably hamper information transmission; *generally* meaningful signs would have a tendency to elicit many different responses, including inappropriate ones. Second, pictorial quality does not appear to be a necessary correlate of specific meaningfulness. This would suggest that the signs could be reduced significantly in complexity without disturbing their specific meaningfulness.

In support of their conclusions, the authors conducted several investigations. Of particular interest are two findings. Specifically, that learning occurs faster on graphic representations than numerical representation of the same concepts. But more relevant to the present discussion, and pertinent to their application, Howell and Fuchs indicate that codes high in "stereotypic content" were the easiest to learn, followed by symbols lower in stereotypic content and finally, by numeric representations of concepts. Similarly, the same relationship was reported for measured response latencies. Symbols judged high on stereotypic content performed significantly better than symbols judged of lesser stereotypic quality, and finally, by numeric representations (judged to possess little stereotypic value).

The authors point out that part of the latency deficit attributable to numeric constructs is because:

> the numbers, apparently, are recognized first as numbers and must be recoded, whereas the graphic symbols convey the meaning of their concepts directly. This is indicated by the significant superiority of the graphics symbols on latency measures: Since the numbers are recognized as accurately as graphic symbols but require longer to process, the extra time must be taken up in recoding operations at a neural level.

Editing Features

The kernel functions required of a word processing system vary depending on the intended sophistication of the system, and source cited. Similarly, the suggested implementation of the functions differ considerably. Table 1, lists the word processing functions identified while conducting the literature review.

Roberts and Moran (1983) identify core[2] editing tasks not as discrete capabilities, but rather as cross-products of operations (in the form of operators) applied to textual objects. For example, the INSERT *operator* can be applied to any of the following *textual objects*: CHARACTER, WORD, LINE, SENTENCE, PARAGRAPH, and SECTION. Similarly, the DELETE operator can be applied to the same set of objects to effect legitimate text editing operations. The universal command set is contrasted with the more traditional approach to the dedicated text processing command set organization/structure and is detailed in Table 1.

Rosenberg (1983), referring to the same concept as "universal" or context-independent commands, relates several prominent features or issues. Specifically, Rosenberg states:

> Since universal commands names such as delete are general words, their semantic features are basic ones, and they have few distinctive features and selection restrictions. These basic features are then augmented by the particular task and action contexts to yield the meaning of the name in a

[2]While the intent was to compile a set of core editing tasks, Roberts and Moran point out that "transpose" is in effect an optimization of two moves and therefore represents an implementation strategy rather than a true core editing task.

Table 1. Word Processing Functions Identified From Literature Review.

Function	Source(s)
Add	Lee & Lochovsky (1983)
	Folley & Williges (1981)
Add blank lines	Lee & Lochovsky (1983)
Add space	Lee & Lochovsky (1983)
Alignment	Lee & Lochovsky (1983)
Alter font	Lee & Lochovsky (1983)
Alter type face	Lee & Lochovsky (1983)
Area	Folley & Williges (1981)
Base-line spacing	Lee & Lochovsky (1983)
Bottom	Folley & Williges (1981)
Break after	Lee & Lochovsky (1983)
Break before	Lee & Lochovsky (1983)
Cancel	Folley & Williges (1981)
Change	Folley & Williges (1981)
Clear Store	Folley & Williges (1981)
Copy	Roberts & Moran (1983)
	Folley & Williges (1981)
Copy character	Roberts & Moran (1983)
Copy line	Roberts & Moran (1983)
	Folley & Williges (1981)
Copy paragraph	Roberts & Moran (1983)
Copy section	Roberts & Moran (1983)
Copy sentence	Roberts & Moran (1983)

Table 1 (continued). Word Processing Functions Identified From Literature Review.

Function	Source(s)
Copy word	Roberts & Moran (1983)
	Folley & Williges (1981)
Delete	Lee & Lochovsky (1983)
	Roberts & Moran (1983)
	Folley & Williges (1981)
Delete character	Roberts & Moran (1983)
Delete line	Roberts & Moran (1983)
	Folley & Williges (1981)
Delete paragraph	Roberts & Moran (1983)
Delete section	Roberts & Moran (1983)
Delete sentence	Roberts & Moran (1983)
Delete to	Folley & Williges (1981)
Delete up	Folley & Williges (1981)
Delete word	Roberts & Moran (1983)
Delete blank lines	Lee & Lochovsky (1983)
Delete space	Lee & Lochovsky (1983)
Display	Folley & Williges (1981)
Display store	Folley & Williges (1981)
Down	Folley & Williges (1981)
Edit	Folley & Williges (1981)
Face detail	Lee & Lochovsky (1983)
Fill	Lee & Lochovsky (1983)
Find	Folley & Williges (1981)
Find up	Folley & Williges (1981)

Table 1 (continued). Word Processing Functions Identified From Literature Review.

Function	Source(s)
Font size	Lee & Lochovsky (1983)
Font type	Lee & Lochovsky (1983)
Footer indent	Lee & Lochovsky (1983)
Header indent	Lee & Lochovsky (1983)
Indent	Lee & Lochovsky (1983)
Input	Folley & Williges (1981)
Insert	Roberts & Moran (1983)
	Folley & Williges (1981)
Insert character	Roberts & Moran (1983)
Insert line	Roberts & Moran (1983)
Insert paragraph	Roberts & Moran (1983)
Insert section	Roberts & Moran (1983)
Insert sentence	Roberts & Moran (1983)
Insert word	Roberts & Moran (1983)
Itemize	Lee & Lochovsky (1983)
Itemize indent	Lee & Lochovsky (1983)
Join	Folley & Williges (1981)
Left	Folley & Williges (1981)
Left margin indent	Lee & Lochovsky (1983)
Mark	Folley & Williges (1981)
Merge	Roberts & Moran (1983)
Merge character	Roberts & Moran (1983)
Merge line	Roberts & Moran (1983)
Merge paragraph	Roberts & Moran (1983)

Table 1 (continued). Word Processing Functions Identified From Literature Review.

Function	Source(s)
Merge section	Roberts & Moran (1983)
Merge sentence	Roberts & Moran (1983)
Merge word	Roberts & Moran (1983)
Move	Roberts & Moran (1983)
Move character	Roberts & Moran (1983)
Move left	Lee & Lochovsky (1983)
Move line	Roberts & Moran (1983)
Move paragraph	Roberts & Moran (1983)
Move right	Lee & Lochovsky (1983)
Move section	Roberts & Moran (1983)
Move sentence	Roberts & Moran (1983)
Move word	Roberts & Moran (1983)
No paragraph	Lee & Lochovsky (1983)
Paragraph	Lee & Lochovsky (1983)
Paste	Folley & Williges (1981)
Paste and erase	Folley & Williges (1981)
Repeat	Folley & Williges (1981)
Replace	Lee & Lochovsky (1983)
	Roberts & Moran (1983)
Replace character	Roberts & Moran (1983)
Replace line	Roberts & Moran (1983)
Replace paragraph	Roberts & Moran (1983)
Replace section	Roberts & Moran (1983)
Replace sentence	Roberts & Moran (1983)

Table 1 (continued). Word Processing Functions Identified From Literature Review.

Function	Source(s)
Replace word	Roberts & Moran (1983)
Return	Folley & Williges (1981)
Right	Folley & Williges (1981)
Right margin indent	Lee & Lochovsky (1983)
Split	Roberts & Moran (1983)
	Folley & Williges (1981)
Split character	Roberts & Moran (1983)
Split line	Roberts & Moran (1983)
Split paragraph	Roberts & Moran (1983)
Split section	Roberts & Moran (1983)
Split sentence	Roberts & Moran (1983)
Split word	Roberts & Moran (1983)
Store	Folley & Williges (1981)
Store and erase	Folley & Williges (1981)
Switch	Folley & Williges (1981)
Top	Folley & Williges (1981)
Transpose	Roberts & Moran (1983)
	Folley & Williges (1981)
Transpose character	Roberts & Moran (1983)
Transpose line	Roberts & Moran (1983)
Transpose paragraph	Roberts & Moran (1983)
Transpose section	Roberts & Moran (1983)
Transpose sentence	Roberts & Moran (1983)
Transpose word	Roberts & Moran (1983)

Table 2. Selected Word Processing Functions

Word Processing Function
Beginning of block
Beginning of line
Beginning of text
Delete line
Delete paragraph
Delete word
Double space
End of block
End of line
End of Text
Footer
Header
Insert Word
Justify
Left justify
Page break
Paginate
Right justify
Single space

> particular situation...Thus, general names allow for explicit composition by adding classes of modifiers and objects (e.g., text-editors often have a delete command which can take several modifiers and objects: delete a word, delete three lines, etc.). The limitations of universal commands is that, since they are so general and unspecific, their meaning in a given context may be vague (e.g., there may be several kinds of **move** possible), or even poorly mapped onto the corresponding action.

While these concerns are more directly relevant to the naive or inexperienced user, they do serve to highlight potential difficulties associated with commands structures for all user populations. It is important to note that the same concerns can be directed at graphical command structures. Without relying on sophisticated interpreters/compilers to determine the legitimacy of compound command strings, there appears to be at least three implementations that can circumvent the problems identified with universal commands. The first alternative, applies more directly to textual representation of constructs than to graphical or iconic constructs, is related by Rosenberg (1983) and relies on the Von Restorff effect (that anomalies stand out). Specifically:

> there is the case where a non-word has no semantic features, and its surface features map either poorly (e.g., "**control-F** means go *F*orward one character")or not at all onto the corresponding action; in this case, since there is little or no similarity, the success of such a name is dependent solely upon its distinctiveness...and that ...its distinctiveness will make it work as long as there are only a few such anomalous names in the nameset.

Thus, the idiosyncrasies need to be either few or very distinctive to effect any discernible differences between commands.

The second approach, is based on iconic programming and involves coding legitimate command relationships by shape. Operators (commands) could be developed such that only meaningful objects could be inserted within or adjacent to them to construct effective text-processing operations. Shape coding would give an indication of legitimate command strings without requiring a trial and error approach. Thus, strengthening and positively reinforcing appropriate command construction (referent-object pairings).

The third approach is essentially a derivative of the second, and involves identification of legitimate constructions by color, shading or dimensions other than shape.

Recognition

In detailing specific design objectives in the design of the Star (Xerox 8010) office workstation, Bewley, Roberts, Schroit, and Verplank (1983) relate four guiding principles derived from cognitive psychology:

> • There should be an explicit user's model of the system, and it should be familiar (drawing on objects and activities the user already works with) and consistent.
>
> • Seeing something and pointing to it is easier for people than remembering a name and typing it. This principle is often expressed in psychological literature as "recognition is generally easier than recall" [Anderson, 1980].
>
> • Commands should be uniform across domains, in cases where the domains have corresponding actions (e.g., deleting a word from text, deleting a line from an illustration, and deleting information from a database).
>
> • The screen should faithfully show the state of the object the user is working on: "What you see is what you get.

In a similar vein, Lee and Lochovsky (1983) relate that "A graphical user interface and direct manipulation allow the user to *recognize and point* instead of *remember and type*". To that end, the authors state that using standard proofreading symbols "help place the electronic text processing operations in a more familiar context for the user."

Age

The effect of age on text processing performance remains in question since research has not conclusively demonstrated a reliable effect. Gomez, Egan, Wheeler, Sharma, and Gruchacz (1983), Rabbitt (1979), Cerella, Poon, and Williams (1980) suggest that age negatively affects word processing performance. Specifically, with respect to acquisition or learning, the deficit has been linked to education level and attitude towards computers (Gomez, Egan, Bowers, 1983). Other investigations have tested the effects of complexity of keyboard responses (Rabbitt, 1979), and information processing capabilities (Cerella, Poon and Williams, 1980). The general findings indicate that as information processing is made more complex (any factor which increases the time to perform a task), older subject's performance is differentially affected.

In evaluating the recognition characteristics of automotive symbols, Jack (1972) reported no significant age or sequence effects.

Allen, Parseghian, and Valkenburgh, (1980) report that older drivers demonstrate less "knowledge of symbol signs than younger drivers ... and past research has shown deteriorated capability with age that would interfere with the retention, processing and recall of symbolic information". These effects can perhaps be explained as a function of symbol exposure. The authors concede the following plausible explanation "...could very well be a generational effect, with younger drivers having had more exposure to symbol signs during driver education and training." This explanation is supported by the Cahill, (1975); Brainard, Campbell and Elkin, (1961); and Kolers, (1969), whose evidence suggest that the more experience an individual has with a particular set of symbols the better the identification performance.

Sex

In evaluating factors that influence response times of pictograms with automotive applications, Green (1980) determined that there was no significant response time difference between male and female subjects. Similarly, Jack (1972) in comparing identification rates of candidate automotive control symbols, determined no significant difference as a function of sex.

While Sloan and Eshelman (1981) did not report a significant performance effect as a function of sex, they did note a significant difference when comparing preference ratings for candidate warning symbols.

Symbol Definition

In developing symbols for industrial applications, Dreyfus (1966) specified two general types or categories:

> *Pictographs*. These look very much like the item, or depict qualities generally associated with the item. They are more easily recognized because some prior association exists.
>
> *Abstractions*. The initial derivation of these is obscure, but the symbol becomes meaningful through education.

Subsequent works by Dreyfus (1972) indicate the necessity to alter the definition of *abstraction* and to add a third category. Correspondingly, he changed the term for pictograph symbol to *Representational* symbol. Accordingly, the following revised definitions are provided.

> *Representational* symbols present fairly accurate, if simplified pictures of objects, or action.
>
> *Abstract* symbols reduce essential elements of a message to graphic terms. These may have been representational but have become simplified by design (or convention) or degrees over many years, to the point where they now exist only as symbolic indications. For example, the signs of the zodiac were once realistic representations of gods or animals, yet today they bear faint resemblance to their original concept.
>
> *Arbitrary* symbols are those that are invented, and accordingly must also be learned (presumably through an additional or separate mechanism(s) required to "acquire" *Representational* or *Abstract* symbols).

Similarly, Glinert (1985), in referring to programming, highlights the following operational distinctions between visual, textual, and iconic programming languages:

> A programming language or system will be termed *visual*, as opposed to *textual*, if one or both of the following conditions hold(s):
>
> - Higher level graphical entities are made available to users as atoms that they may/are required to manipulate when programming or that their programs may manipulate in the run-environment. By "higher level graphical entities" we mean here geometric objects such as circles, or in general any sort of image excluding those that represent individual characters in the standard programming alphabet (where "alphabet" is used in the formal language theory sense), but not the mere ability to reference individual pixels.
>
> - Graphical elements (which may contain text, numbers, *etc.* as components) form an integral and essential (as opposed to merely decorative) part of the display generated by the system for the user in either the programming or run-time environment.

> A visual programming system will be called *iconic* if the programming process is essentially one of selecting and/or composing icons and placing them in proper juxtaposition with one another on the screen. As it is permissible that icons overlap, we will assume that, like overlay planes for a single frame in an animated cartoon, they are "drawn" on transparent backgrounds.

Founded in the above definitions, the following section details the usage of terms used when referring to symbolic constructs. The distinction between *graphic* and *iconic* representations appear to be more one of semantics than of substance, as the important quality or characteristic rests in symbolic representation of a concept as opposed to the "completeness" of a structure. Therefore, for purposes of the present discussion, the two terms will be considered interchangeable. However, where appropriate and necessary, a distinction will be maintained between *pictographs* and *abstractions*.

Textual representations are defined as constructs that are limited by design to rely solely on utilization of English textual characters to transmit intended meaning.

Mixed or combined representations refer to representations constructed of both textual and graphic elements (whether pictographs [representational] or abstractions) to convey their intended meaning.

Symbol Development

In summarizing efforts in developing symbols for use in industrial and farm machinery, Dreyfus (1966) provides the following insights and observations relative to operational mechanisms of symbols:

> 1. Consistency. Certain basic elements, both objective and nonobjective, began to repeat themselves among the various symbols.
>
> *Objective elements:* tangible objects like transmission, engine, tractor, and combine. ENGINE is represented by a simplified outline of cylinder and crankcase. TRANSMISSION is depicted by a gear. TRACTOR, shown in plan view silhouette. COMBINE, shown in side view silhouette.
>
> *Nonobjective elements:* intangible qualities like temperature, movement, adjustment or measure, and direction. TEMPERATURE is symbolized by a thermometer. ROTATIONAL MOTION is shown as a curved arrow. LINEAR MOTION as a straight arrow. ADJUSTMENT or

MEASUREMENT are implied by use of the "dimension line" symbol. UP and DOWN are relative and must be shown with some reference.

Once a graphic representation has been designed or adapted for theses elements, it should be applied consistently wherever required. As these elements reappear in different combinations, their symbolic association is reinforced and operator recognition is increased.

2. Operators intelligence and familiarity. It is assumed that the operator would have reasonable intelligence and an average amount of general mechanical knowledge, coupled with some degree of familiarity with the operations of agricultural and industrial equipment.

3. Frequency of use or exposure. During the normal use cycle, the operator would use some controls more than others. Controls used quite often could be identified by relatively "abstract" symbols since the frequency of use would continuously reinforce the symbolic association or reference. More pictographic symbols would be applied to infrequently used controls because the strong pictorial association reduces learning time and increases operator retention.

4. Identification. One of the main functions of a symbol is to identify the item and explain the "effect" when the control is actuated.

5. Directional action. By design, the direction a control moves in corresponds, in most instances, directly to the movement of the actuated mechanism. Therefore, when a symbol conveys action, it is the *resultant* action of the mechanism.

6. Proximity. The design of a symbol is influenced by its proximity to the item it identifies. If the symbol is on or immediately adjacent to the item, it can be "abstract," since the actual item reinforces the symbolic association. But, if a control is quite remote from the mechanism it actuates, the symbol should be more pictographic.

Implementation

As determined and reported by Gomez, Egan, Wheeler, Sharma, and Gruchacz (1983), and Roberts and Moran (1983) text processors utilizing line editors have been demonstrated to: require more training, increase errors and take longer to affect the same set of operations than full screen editors. As the proposed effort is directed at comparing several representation "technologies" of select word processing features, the constructs evaluated are limited to the those required for manipulation of text. This is at the exclusion or expense of *file level* operations such as save, copy, or merge, which would necessarily transcend all application programs.

The successful utilization of graphical interfaces is dependent on several characteristics, not the least of which is the particular functional representation(s) of the command set. Similarly, the implementation of a particular interface can enhance or detract from an otherwise useful interface.

The success of graphically representing a concept is partially a function of what the user is attempting to achieve, and similarly, how well the concept is formulated in his/her mind (thus the primary rationale for selecting word processing). Additionally, the utility of the graphical interface is a function of how well competing interfaces perform. Simple application programs predicated on textual interfaces may achieve the required levels of performance using non graphical (textual) interfaces. The proposed study is not an attempt to address all of these issues, rather it is an attempt to determine the first in a series of related questions, specifically, whether performance can be attributed to a particular set of graphical representations. After resolution of the general issue, consideration should be given to investigating the most efficient implementation(s), applications, and definition of the variables that determine the specific performance characteristics.

Selection of Independent Variables

As detailed in the introduction, significant resources have been committed to the development of graphical interface technologies without empirical evidence for their superiority. An important, unanswered question is, "When, and under what conditions, should a graphical interface should be utilized?". Presumably, the answer would center on the performance characteristics of the competing technologies as a function of the particular application.

In an attempt to identify some of the performance characteristics of the competing interface technologies, the present effort has identified and reviewed research to determine the potential relevance of: Experience, Stereotypical Expectations, Age, and Sex, as related to word processing.

As detailed below, the literature supported incorporation of four independent variables: *Experience*, *Format*, *Setblock* and *Session*. The specifics of each variable are detailed below, under the appropriate heading.

Experience.

For the present effort, experience was evaluated with respect to application experience. The word processing functions were borrowed from Scripsit (Tandy Corporation 1979) and WordStar (MicroPro, 1982). Individuals indicating practical knowledge or experience (as determined from the participant eligibility form) of either program were not considered as subjects. The iconic stimuli were developed explicitly for the present effort (and are believed to be unique). Therefore, construct experience should initially be the same across all subjects and application experience can be evaluated without consideration of construct experience confounds.

The selection of the word processing functions was driven by several related factors. First, review of several popular word processing software packages revealed common word processing functions.

Secondly, the selected word processing functions were thought to cover the spectrum in terms of functional clarity. For example, it was expected that few subjects would have difficulty differentiating between the single spacing and double spacing word processing functions. However, it was expected that subjects would experience difficulty differentiating between the justification and left justification functions. The resulting stimuli were developed in an attempt to include a wide variety of word processing functions such that presentation format could be fully exercised.

Finally, it was thought that using subjects with no first hand knowledge of the command representations would provide a realistic basis for relating results to real world applications. The selected word processing functions are provided as Table 2.

Stereotypical Expectations.

It has been demonstrated that stereotypical expectations facilitate the interpretability of symbols (Brainard, Campbell and Elkin, 1961). Stereotypical expectation is a strong corollary to experience and therefore no attempt was made to systematically vary the stereotypic qualities of representations. However, Howell and Fuchs (1968), have demonstrated that stereotypic data can be derived from response data. It was expected that an indirect indication of stereotypic expectations would be captured and demonstrated via the preference ratings as proposed in the preference rating task.

Age.

The literature suggests that while no age effect has been conclusively demonstrated, word processing performance is negatively affected when complex physical response modes are required. Specifically, older subject performance is differentially affected when compared to younger subjects performance measures. Therefore, a safeguard was incorporated into the experimental method. Specifically, a verbal response mode eliminates any potential response mode confounds.

Additionally, age was not included as an independent variable because of serious potential confounds with experience. Without significant evidence supporting the contrary, it was deemed inappropriate to shoulder the burden of more complicated experimental and statistical procedures. However, to minimize potential difficulties in the interpretation of results, subjects were matched (or yoked) for age across experience groupings.

Sex.

While word processing in the workplace has traditionally been dominated by females, there is no evidence that suggest any significance performance differences as a function of sexual differences. Similarly, no evidence was available to support a response performance (as measured by speed or accuracy) differential as a function of inherent sexual differences. Therefore, sex was not considered as an independent variable. However, as with age, subjects were matched for sex across experience levels.

Setblock.

In addition to determining if format (terminology technology) impacts performance, an additional objective of the study was to determine if command sets produced by the application of varying rule sets would produce command representations of varying quality. Therefore, a review of existing standards, guidelines and research findings was conducted and results compiled into rule sets. The resulting rules and rationale are provided below.

Text Sets.

While a wide variety of procedures have been proposed for developing abbreviations, a set detailed in Bailey (1982) indicates that subjects were able to remember more of the rule-based abbreviations than subjects who attempted to memorize commonly used commands. Bailey reports that Streeter, Ackroff and Taylor (1980);

> had a group of subjects generate abbreviations for a number of commonly used commands. They then derived a set of rules based on how these subjects produced their abbreviations. Rule-based abbreviations were

compared to the most frequently given abbreviations for each command... another group of subjects remembered substantially more of the rule-based abbreviations than did subjects who studied the frequently-produced abbreviations.

The proposed rule-based abbreviation schemes are as follows:

- For terms consisting of more than one word:
  - take the first letter of each word as the abbreviation

- For monosyllabic words:
  - take the initial letter of the word and all subsequent consonants
  - make double letters single
  - if more than four letters remain:
    - retain the fifth letter if part of a functional cluster (*th, ch, sh, ph, ng*)

  otherwise:

    truncate from the right
    - delete the fourth letter if it is silent in the word.

- For multisyllabic words:
  - take the entire first syllable
  - if second syllable starts with a consonant cluster, add it
  - if the first syllable is a prefix and the second syllable starts with a vowel, add the second syllable
  - make double consonants single
  - truncate to four letters (but always retain entire first syllable).

The textual representations labeled as Set 1 (basic) in Appendix E were developed by application of the first procedure. Similarly, Set 2 (enhanced) representations were developed by applying the remaining two rules as appropriate.

Icon Sets

While several methods or procedures detailing how to develop abbreviations have been published and are readily available in the literature, no analogous procedures have been identified for icon development. However, by integrating the findings of several research efforts, specifications, and guidelines, a reasonable procedure can be developed. Such a procedure is detailed below and was employed for developing the icons in the basic set.

- Identify the functional requirements of the system (i.e., file storage, file retrieval)

- Classify similar or related functions into function classes (i.e., file manipulation - storage, retrieval)
- For each functional class, develop a standard symbol (or template) of the referent. Pictorial representations (e.g., caricatures) are generally easier to interpret and recognize than abstract symbols (e.g., circle with a 'slash').
- Evaluate the proposed template against all other system function requirements to verify that subsequent alterations can be achieved without modify the basic function class template.
- Refine the function class template by application of the following guidelines as needed to represent the essential characteristics of the function.
  - design pictorial symbols (e.g., icons, pictograms) to look like the objects or processes they represent (Smith and Mosier, 1986)
  - use arrows to show functionality and manipulative information (Rohr and Keppel, 1984)
  - be consistent with any 'themes' (i.e., the symbol for *delete* in delete word should be the same as the symbol for *delete* in delete paragraph) that are developed across icons, unless there is an explicit rationale for violating the theme. (Bewley, Roberts, Schroit and Verplank, 1983)
  - the shape of the icon is not critical as long as its pictorial quality remains intact (Bewley, Roberts, Schroit and Verplank, 1983)
  - a symbol should be demonstrably different from its background (Easterby, 1970)
  - solid boundaries should be used to provide background contrast (Easterby, 1970)
  - test the resulting symbol set with a representative group of users

As indicated by Rohr and Keppel (1984), arrows were used extensively. Specifically an arrow was used to connote one of two concepts, depending on whether it exists alone or paired with a secondary indicator (i.e., line). The arrow alone indicates a relative location (i.e., end of file, beginning of line). The arrow used in conjunction with a secondary feature (solid vertical line), indicates manipulation of the referent object with respect to the secondary indicator (i.e., justify).

Additional coding or indicators used in developing the basic set and their assigned significance include:

- box; select and/or act on a select region of the icon (i.e., delete line. delete paragraph)
- solid horizontal line; demarcating a specific region of an icon (i.e., footer, header)
- dashed horizontal line; used in conjunction with arrows. Because all relative motion does not occur with respect to the horizontal axis (left to right), it was necessary to develop an equivalent indicator for the vertical axis (top to bottom). The solid horizontal line is used to demarcate a

specific region. The solid vertical line is used as a secondary indicator. A dashed line used in conjunction with the arrows is used to indicate relative movement in the vertical axis (i.e., paginate).

The enhanced icons represent the basic icons modified by adding an additional cue or indicator to the active area of the basic icon set. Specifically, where arrows are used, they are encompassed by a circle. Where a box is used, it is filled in solid. Where the horizontal line was used in the basic set to denote an area, the area is filled in with a matrix (gray) fill in the enhanced set.

Session.

A session or block variable was considered as an independent variable. While no studies were reviewed that analyzed the relationship between time and performance, it was felt that by maintaining a one week interval between the acquisition and secondary recall session, subjects' long term recall would be fully evaluated.

Selection of Dependent Measures

A principle reference source utilized in the formulation of the methodology and approach presented for the proposed effort is founded on efforts conducted by Roberts and Moran (1983). In addition to reliance on their efforts in developing core or editing requirements (kernel word processing functions Table 1), the dependent measures are extracted from the same work. As related by Roberts and Moran (1983), time to perform basic editing tasks by experts; error costs for experts, learning of basic editing tasks by novices; and functionality over a wide range of tasks are "... four dimensions of editor usage that are behaviorally fundamental and practically important". However, it should be noted that the work reported by Roberts and Moran (1983) was directed at developing a methodology for examination and evaluation of existing word processing application programs. Therefore, as detailed below, liberty was taken with the definition and application of select dependent measures.

Comparative research is typically conducted to ascertain the relative merits of one approach over another. To correctly evaluate alternative approaches, it is appropriate to use the "operational context" and idiosyncrasies designed into a system. Specifically, the total "effect" or efficiency of a system is the sum of its constituent parts. Therefore, implementations as a whole are evaluated and compared. The present effort diverges from this approach because of its target objective. Specifically, the present effort was an attempt to determine specific characteristics (acquisition, primary and secondary recall attributes) as a function of command presentation format (icon, text, mixed).

To achieve this objective, it was necessary to evaluate the commands with respect to functional referents (i.e., word processing functions) independently of "implementation" or "context" referents (i.e., Wordstar, Scripsit).

Response Time

Acquisition, primary and secondary recall response times were selected as dependent measures of performance (*cf* Roberts and Moran, 1983) because they are an integral aspect of command utilization. It is necessary to select an appropriate command prior to implementing or applying it. Therefore, it was reasoned that identification of the appropriate command as opposed to application of the command (which is a function of implementation), is all that is required to evaluate the effectiveness of one presentation format over another.

Response Errors

While time to respond indicates an useful index of presentation effectiveness or efficiency, it is not the only meaningful aspect. Error data may indicate that while some representations may be processed quickly, they may be interpreted incorrectly.

Response Mode

As a measure of effectiveness, correct selection and utilization of a command indicates: a quantification of absolute understanding (what the function achieves independently of representational format) of it's functional or operational characteristics; and relative (utility of a particular presentation) efficiencies of a particular presentation format.

The degree to which an implementation can be isolated from an effect, the more effective or sensitive the evaluation. Therefore, it was reasoned that a verbal response, as measured by response time and response errors would minimize potential confounds of presentation effect as a function of experience.

Implementation

Development of a text editor (and associated text editing tasks) that would support the various command formats, would not only unnecessarily increase the effort required to conduct a comparative analysis, but would seriously confound results with an "editor effect" . More precisely, the determination of the relative merits of an interface should not be tainted by any particular implementation. Therefore, the degree to which the dependent variable reflects the "true" nature of an effect is at least partially a function of the ability to isolate the effect from the inherent biases of a particular implementation. For this reason, verbalization of the intended meaning of a representation is thought to be free of any differential contaminates.

Additionally, the proposed approach minimizes variables that might differentially penalize naive subjects (when compared to more experienced counterparts), such as mode of response. The agility and dexterity of experienced word processors due to more developed muscle coordination could presumably confound presentation effects.

Finally, utilization of any text editor (existing or developed) would differentially benefit more experienced users. Presumably due to generic experience with text editor interface devices (i.e., keyboard, mouse).

Method

Subjects

Thirty subjects were recruited from the surrounding academic and business communities. Specifically, interested subjects were drawn from George Mason University and from local business interests which require individuals with the requisite word processing expertise (Appendix A).

The specific make up of subjects is detailed in Figure 1. In an attempt to minimize potential confounds associated with age and sex, subjects were matched with regard to those characteristics.

Prior to acceptance as subjects, candidates were requested to read an experiment description/consent and disclosure form (Appendix B). The form served to emphasize the importance of candidate credentials, as well as to iterate that while a 'permanent' record of subjects responses was to be made, subject's rights to confidentiality were to be protected. Additionally, the payment schedule and forfeiture clause were clearly explained in writing. Both subjects and the experimenter attested to their understanding of the terms by signing and exchanging copies of the consent form.

Candidate credential forms were examined to determine the adequacy of the available pool(s) of potential subjects. After determination of an adequate pool, subjects were randomly selected and assigned to an appropriate experimental condition.

As a major reason for conducting the research was to permit the comparison of the acquisition and retention qualities of icons and text representations, within-subject abilities were of primary importance. Therefore, subjects were requested to participate in two sessions. The sessions were scheduled one week apart.

Experience

		Low		Medium		High	
		Male	Female	Male	Female	Male	Female
	16 - 25	S1	S6	S11	S16	S21	S26
	26 - 35	S2	S7	S12	S17	S22	S27
Age	36 - 45	S3	S8	S13	S18	S23	S28
	46 - 55	S4	S9	S14	S19	S24	S29
	56 - 65	S5	S10	S15	S20	S25	S30

Low — Subject reported no word processing experience.

Medium — Subject reported either word processor experience
or
experience with a word processing program.

High — Subject reported either word processor experience
and
experience with a word processing program.

Figure 1. Subject Characteristics by Experimental Group

Apparatus and Materials

Apparatus

Preliminary estimates of response times indicated expected time intervals would be less than thirty seconds. Additionally, the practical requirements associated with randomization as well as concerns for logging and analyzing large amounts of data highlighted the necessity of using a computer. Other experimental considerations (manipulation of graphic as well as textual strings) suggested the Apple Macintosh was the computer of choice. The specifics of the hardware configuration and software requirements are detailed below.

Computer

The standard Macintosh Plus hardware configuration including: keyboard; mouse; (800 K) external disk drive; and Imagewriter I dot matrix printer were utilized.

Stimuli

The stimuli used in the study were developed using Fontastic, a bit mapped font editor available for the Macintosh computer. A font editor was used to eliminate the "paint" time associated with exciting a large number of pixels over a wide screen area. The stimuli were stored on disk, loaded into memory at startup, and otherwise treated as if they existed as a standard font set. Therefore, it took the same amount of time to present a stimuli as to paint a single character.

Software

The software controlling the presentation and data management functions was written in Microsoft BASIC (2.10). Complete software listings are included as Appendix G. Other programs required to transform data into formats compatible with the data analysis software were also created in BASIC.

A second software package, Typing Tutor III (Kriya Systems, Inc) was used to determine subject typing ability.

Design and Procedure

Procedure

The procedure employed consisted of five separate tasks. Specifically, subjects were requested to participate in a practice task, acquisition task, primary recall task, secondary recall task and finally, a preference rating task. The relationship between acquisition, primary and secondary recall tasks is depicted in Figure 2. Figure 2 demonstrates the sequential nature of the tasks involved, and the allocation of subjects among the various experimental conditions. The particular requirements associated with each task are detailed below in turn.

Practice Task. To assist subjects in becoming proficient in the experimental procedure, they were requested to preview a set of slides, and to participate in a practice task that effectively paralleled the experimental procedure. The practice stimulus set utilized was based on work described in Green (1980), in which stimuli were selected "... on the basis of being easily identified, fairly discriminable and easily drawn." Specifically, a set of sample stimuli was developed which consisted of symbols commonly found in public facilities (e.g., airports, roadways, restaurants).

With the exception that the stimuli used in the practice trials did not represent word processing functions, the practice trials replicated the basic characteristics of the acquisition, primary and secondary recall task procedures.

In addition to providing experience with the format and acquisition characteristics of each trial, the practice task also provided an opportunity for subjects to exercise the required response mode, and to demonstrate that they fully understood the operation of the computer. The response segment of each trial required subjects to depress a mouse button,

Experience Level	Session 1						
	Practice Task	Acquisition Task			Primary Recall Task		
		Presentation Format			**Presentation Format**		
		Icon	Text	Mixed	Icon	Text	Mixed
Low	S1-S10	S1-S10	S1-S10	S1-S10	S1-S10	S1-S10	S1-S10
Medium	S11-S20	S11-S20	S11-S20	S11-S20	S11-S20	S11-S20	S11-S20
High	S21-S30	S21-S30	S21-S30	S21-S30	S21-S30	S21-S30	S21-S30

Experience Level	Session 2					
	Secondary Recall Task			Preference Rating Task		
	Presentation Format			**Presentation Format**		
	Icon	Text	Mixed	Icon	Text	Mixed
Low	S1-S10	S1-S10	S1-S10	S1-S10	S1-S10	S1-S10
Medium	S11-S20	S11-S20	S11-S20	S11-S20	S11-S20	S11-S20
High	S21-S30	S21-S30	S21-S30	S21-S30	S21-S30	S21-S30

Figure 2. Experimental Design

and to simultaneously provide a verbal response. While the response mode did not require exceptional coordination, it was necessary to 'prompt' or remind subjects that a significant aspect of the experiment was their verbal response.

In the practice and acquisition tasks, the verbal response required the subject to read the "correct designation" that was provided as part of each stimuli. As depicted in Appendices D and E respectively, designations were provided during the practice and acquisition tasks, but were omitted in the primary and secondary recall tasks.

The designation was presented as a twelve point (1/6 inch) legend centered approximately 1/2 inch from the bottom margin of each chart. At the subject viewing distance of 2 feet, the legend translates to approximately twenty-four arc minutes[3]. As reported in Grether and Baker (1963), the minimum acceptable visual angle is 10 arc minutes, where the preferred minimum is equal to fifteen arc minutes.

Finally, the practice session provided the experimenter an opportunity to verify that subjects could read.

Acquisition Task. Upon completion of the practice set, subjects were requested to examine the representations of word processing functions at their own pace. Again, stimuli were presented via the computer (a description of the display aspects of the experiment is

---

3 Visual angle (min.) $= (57.3)\,(60)\,\dfrac{L}{D}$ [1]

Where L = the size of the object as measured perpendicular to the line of sight, and D = distance between the object and observers eye reference point.
To verify that the 12 point lettering meets the "preferred" arc minute requirements at a viewing distance of two feet, it is necessary to transform points to inches. A point is defined to equate to 1/72th of an inch. Therefore, 12 points = .166 inches (.013888 inches per point). Substitution of .166 and 24 for L and D respectively in [2] results in [3].

$$= (57.3)\,(60)\,\frac{.166}{24} \qquad [2]$$

$$23.778 \quad = (57.3)\,(60)\,\frac{.166}{24} \qquad [3]$$

provided in the apparatus section). As with the practice task, subjects were provided instructions appropriate to the task via the computer screen (the complete instruction set is provided as Appendix C). The instructions specific to the acquisition task were:

> For each screen or slide, you are to:
> - read the designation aloud
> - view each slide as long as you feel is necessary, such that you could reliably provide the proper designation if requested to do so.

When a subject had determined that he/she could provide the proper designation, he/she read the legend aloud, and simultaneously activated the "I got it!" button. The screen was cleared and replaced by a screen containing only a "ready" button. When the subject was ready to proceed with the next trial he/she activated the "ready" button and the computer presented the next stimuli. A "time out" screen was inserted between trials in an attempt to keep the response time measure uncontaminated. In all tasks, response time was defined as the time interval between presentation of the stimuli, and activation of the "I got it!" button. Therefore, activation of the "I got it!" button was designed to signal completion of a trial and did not explicitly indicate that a subject was ready to proceed to the next trial. The "time out" screen was used throughout all tasks of the study.

To control for potential sequence confounds, presentation order was randomized prior to each task. This precaution was required to minimize the confounding potential of the "combined" or mixed representations (Appendix E). As the term implies (and is defined), mixed representations contain elements common to both iconic and textual command representations. Thus, if no control was placed over the presentation sequence, a "practice" or exposure effect might affect the response characteristics of subsequent stimuli that possess the common command elements. To exemplify, having been presented the mixed representation of the paginate function first, a subject might benefit from that exposure when subsequently presented the iconic representation of paginate.

Similarly, in the primary and secondary recall tasks, stimuli presentation order was randomized. Randomization and slide ordering was determined by a module of the BASIC program (described in more detail in the Apparatus section).

Examination of the acquisition stimuli in Appendix E reveals that the stimuli have equivalent representations in form (e.g., multiple iconic representations) as well as across presentation format (iconic, textual and combined).

As related in the literature review, stimuli development was aided by the application of a set of guidelines. The guidelines represent an attempt to integrate the general findings and recommendations available in the literature. Due to inconsistencies in the literature, the formation of a set of all complete guidelines was not possible. Therefore, a compromise was met by developing two sets for each format.

Additionally, the guidelines attempted to standardize and preserve the basic or fundamental characteristics of each format while allowing for the variability required to depict each function.

In addition to accommodating discrepancies in the literature through the development of two sets of guidelines for each format, it was hoped that by evaluating the response characteristics as a function of guidelines, it would be possible to compare the merits of competing interface technologies without having to evaluate the stimuli proper.

Presentation sequence was monitored and electronically captured via the computer program such that viewing time per representation could be evaluated subsequent to each session for all subjects.

The acquisition, primary, and secondary recall tasks are considered classical learning tasks (as opposed to threshold determination or target detection tasks). Accordingly, stimuli were designed to cover a minimum visual field of one hundred forty-three (143) arc minutes[4] (1 inch at a viewing distance of twenty-four inches), corresponding to the 3/4 inch "target", as employed by Green (1980) at a viewing distance of eighteen inches.

While not considered an independent variable, contrast ratio of stimuli to the display was held constant across all subjects.

Upon completion of the acquisition task (the final slide of the set indicated that the initial segment of the session was complete), subjects were provided the instructions necessary for completion of the next phase (Appendix C).

Prior to initiation of the primary recall task, subjects were granted a rest period of 10 minutes. This break facilitated separation of the training period from the subsequent session and served to standardize the time interval between sessions and across subjects.

Primary Recall Task. With a single exception, the primary recall task followed the same format as the acquisition task. There was a subtle difference in the way subjects responded to stimuli. In the primary recall task, subjects were requested to provide, to the best of their ability, the proper designation of each stimuli. This is contrasted with the practice and acquisition tasks in which subjects were provided the appropriate designation. As in the acquisition task session, subjects controlled the presentation rate. Similarly, as

---

4 Where L = the required size of the object as measured perpendicular to the line of sight. D = 72 inches (the distance between the object and the eye reference point). To determine comparative arc minutes, (with respect to Green, 144 minutes of arc) six feet was used to solve for L (in inches).

$$144 \text{ (minutes of arc)} = \frac{(57.3)(60)(L)}{24} \qquad [4]$$

$$144 \text{ (minutes of arc)} = \frac{(3438)(L)}{24} \qquad [5]$$

$$144 \text{ (minutes of arc)} = (47.75)\ (L) \qquad [6]$$

$$\frac{144 \text{ (minutes of arc)}}{(47.75)} = 3.015 \text{ inches} \qquad [7]$$

with the acquisition task, subject data were recorded via the computer program, enabling evaluation of subject responses for correctness and response time.

Completion of the primary recall task ended the first experimental session for subjects. Subjects were requested to schedule a second session. The second session was one week after the first.

Secondary Recall Task. In the secondary recall task, subjects were reminded of the experimental procedure via presentation of the instruction set (used in the first session), and by presentation of the practice set.

The secondary recall task replicated the primary recall task. Subjects were presented the same set of slides as presented in the primary recall task and were requested, to the best of their ability to provide the correct designation of each representation.

Subject responses were monitored via the computer program and captured on disk, thus permitting the evaluation of subject responses and response times.

Rating Task. Upon completion of the secondary recall task, subjects were requested to complete a preference survey (Appendix F). The survey consisted of an instruction set, and a hardcopy of all stimuli subjects had previously viewed. The rating sheet format was such, that all representations corresponding to a particular word processing function were included as a single collection. Subjects were requested to rank order the representations based on their preference.

Upon completion of the survey (and experiment), interested subjects were provided a debriefing on the objective of the experiment.

Design

As the effort was an investigation into how acquisition and recall are affected by presentation format (icon, text and mixed) as a function of word processing experience, a mixed-factors design was employed (sometimes referred to as split-plot design).

Presentation format and session (primary, secondary recall) are within-subject factors while experience is necessarily a between-subject factors (Within-Within-Between model). Utilizing a mixed factors design increases the efficiency of the experiment when compared to a complete between-subjects design. The increased efficiency is predominantly a result of minimizing the variance across trials that is attributed to inherent subject differences.

An additional advantage of the within-subject factor is that for a given statistical power level, the within-subject design requires a smaller subject pool (thus simplifying subject recruitment and data collection procedures).

The Summary table for the three way mixed factors design analysis of variance (ANOVA) is presented in Table 3. Table 4 lists the summary table for three-way Within-subjects ANOVA for the study. Table 4 denotes the specific levels and degrees of freedom for each independent variable. Otherwise the table is essentially the same as Table 3.

As the selected independent variables were not intended to represent a random sample from all possible levels, the general experimental model is the fixed-effects model.

Independent variables include: presentation format (icon, text and mixed), experience (low, medium, and high), command set (basic, enhanced) and session (primary and secondary recall). Dependent measures include: acquisition time, response times (primary and secondary recall), and response errors (primary and secondary recall).

To assess the presence of functional differences between the independent variables, an ANOVA procedure was applied to each set of dependent measure data. Where appropriate significant effects were subsequently investigated via application of a post hoc test procedure discussed below. Finally, subject preference measures were correlated with dependent measure data to determine how they were related. The findings associated with each analysis are detailed below.

Table 3. Summary Table: Mixed Factors Design - Three-way ANOVA

Source	df	SS = Sum of Squares	MS = Mean Squares	F
Between-Subject	$s - 1$	$SS_S = \sum T^2_S/n_S - G^2/N$		
A	$a - 1$	$SS_A = \sum T^2_A/n_A - G^2/N$	$MS_A = SS_A/(a - 1)$	$F_A = MS_A/MS_{E:BS}$
Error: Between-Subjects	$s - a$	$SS_{E:BS} = SS_S - SS_A$	$MS_{E:BS} = SS_{E:BS}/(s - a)$	
Within-Subjects	$s(bc - 1)$	$SS_{WS} = SS_{TOTAL} - SS_S$		
B	$b - 1$	$SS_B = \sum T^2_B/n_B - G^2/N$	$MS_B = SS_B/(b - 1)$	$F_B = MS_B/MS_{E1:WS}$
C	$c - 1$	$SS_C = \sum T^2_C/n_C - G^2/N$	$MS_C = SS_C/(c - 1)$	$F_C = MS_C/MS_{E2:WS}$
AB	$(a - 1)\cdot(b - 1)$	$SS_{AB} = \sum T^2_{AB}/n_{AB} - SS - SS_B - G^2/N$	$MS_{AB} = SS_{AB}/(a - 1)(b - 1)$	$F_{AB} = MS_{AB}/MS_{E1:WS}$
AC	$(a - 1)\cdot(c - 1)$	$SS_{AC} = \sum T^2_{AC}/n_{AC} - SS_A - SS_C - G^2/N$	$MS_{AC} = SS_{AC}/(a - 1)(c - 1$	$F_{AC} = MS_{AC}/MS_{E2:WS}$
BC	$(b - 1)\cdot(c - 1)$	$SS_{BC} = \sum T^2_{BC}/n_{BC} - SS_B - SS_C - G^2/N$	$MS_{BC} = SS_{BC}/(b - 1)(c - 1$	$F_{BC} = MS_{BC}/MS_{E3:WS}$
ABC	$(a - 1)\cdot(b - 1)\cdot(c - 1)$	$SS_{ABC} = \sum T^2_{ABC}/n_{ABC} - SS_A - SS_B - SS_C - SS_{AB} - SS_{AC} - SS_{BC} - G^2/N$	$MS_{ABC} = SS_{ABC}/(a - 1)\cdot(b - 1)(c - 1)$	$F_{ABC} = MS_{ABC}/MS_{E3:WS}$
Error: Within-Subjects	$(bc - 1)\cdot(s - a)$	$SS_{E:WS} = SS_{WS} - \sum T^2_{ABC}/n_{ABC} + G^2/N + SS_A$		
Error1: Within-Subjects	$(b - 1)\cdot(s - a)$	$SS_{E1:WS} = \sum T^2_{ABS}/n_{ABS} - G^2/N - SS_S - SS_B - SS_{AB}$	$MS_{E1:WS} = SS_{E1:WS}/(b - 1)(s - a)$	

$Error_2$: Within-Subjects	$(c - 1) \cdot (s - a)$	$SS_{E2:WS} = \sum T^2_{ACS}/n_{ACS} - G^2/N - SS_S - SS_C - SS_{AC}$	$MS_{E2:WS} = SS_{E2:WS}/(c - 1)(s - a)$
$Error_3$: Within-Subjects	$(b - 1) \cdot (c - 1) \cdot (s - a)$	$SS_{E3:WS} = SS_{E:WS} - SS_{E1:WS} - SS_{E2:WS}$	$MS_{E3:WS} = SS_{E3:WS}/(b - 1)(c - 1)(s - a)$
Total	$N - 1$	$SS_{TOTAL} = \sum X^2 - G^2/N$	

Table 4. Summary Table: Mixed Factors Design - Three-way ANOVA

Source	df	SS = Sum of Squares	MS = Mean Squares	F
Between-Subjects	9	$SS_S = \sum T^2{}_S/n_S - G^2/N$		
Experience (A)	2	$SS_A = \sum T^2{}_A/n_A - G^2/N$	$MS_A = SS_A/(a-1)$	$F_A = MS_A/MS_{E:BS}$
Error: Between-Subjects	7	$SS_{E:BS} = SS_S - SS_A$	$MS_{E:BS} = SS_{E:BS}/(s-a)$	
Within-Subjects	50	$SS_{WS} = SS_{TOTAL} - SS_S$		
Format (B)	2	$SS_B = \sum T^2{}_B/n_B - G^2/N$	$MS_B = SS_B/(b-1)$	$F_B = MS_B/MS_{E1:WS}$
Setblock (C)	1	$SS_C = \sum T^2{}_C/n_C - G^2/N$	$MS_C = SS_C/(c-1)$	$F_C = MS_C/MS_{E2:WS}$
Experience x Format (AB)	4	$SS_{AB} = \sum T^2{}_{AB}/n_{AB} - SS_A - SS_B - G^2/N$	$MS_{AB} = SS_{AB}a-1)(b-1)$	$F_{AB} = MS_{AB}/MS_{E1:WS}$
Experience x Setblock (AC)	3	$SS_{AC} = \sum T^2{}_{AC}/n_{AC} - SS_A - SS_C - G^2/N$	$MS_{AC} = SS_{AC}/(a-1)(c-1)$	$F_{AC} = MS_{AC}/MS_{E2:WS}$
Format x Setblock (BC)	3	$SS_{BC} = \sum T^2{}_{BC}/n_{BC} - SS_B - SS_C - G^2/N$	$MS_{BC} = SS_{BC}/(b-1)(c-1)$	$F_{BC} = MS_{BC}/MS_{E3:WS}$
Experience x Format x Setblock (ABC)	4	$SS_{ABC} = \sum T^2{}_{ABC}/n_{ABC} - SS_A - SS_B - SS_C - SS_{AB} - SS_{AC} - SS_{BC} - G^2/N$	$MS_{ABC} = SS_{ABC}/(a-1)\cdot(b-1)(c-1)$	$F_{ABC} = MS_{ABC}/MS_{E3:WS}$
Error: Within-Subjects	35	$SS_{E:WS} = SS_{WS} - \sum T^2{}_{ABC}/n_{ABC} + G^2/N + SS_A$		
Error1: Within-Subjects	14	$SS_{E1:WS} = \sum T^2{}_{ABS}/n_{ABS} - G^2/N - SS_S - SS_B - SS_{AB}$	$MS_{E1:WS} = SS_{E1:WS}/(b-1)(s-a)$	

$Error_3$: Within-Subjects	7	$SS_{E2:WS} = \sum T2_{ACS}/n_{ACS} - G2/N - SS_S - SS_C - SS_{AC}$	$MS_{E2:WS} = SS_{E2:WS}/(c - 1)(s - a)$
$Error_3$: Within-Subjects	14	$SS_{E3:WS} = SS_{E:WS} - S_{E1:WS} - SS_{E2:WS}$	$MS_{E3:WS} = SS_{E3:WS}/(b - 1)(c - 1)(s - a)$
Total	179	$SS_{TOTAL} = \sum X2 - G2/N$	

Prior to a description of selected statistical methods, a discussion detailing definitions of the dependent measures is presented below.

Definitions

Acquisition Time. Acquisition time was defined as the time subjects spent reviewing each particular representation. Operationally defined, acquisition time represents the elapsed time between the subject initiated presentation of a stimuli and subject termination of the trial. As implied by the term, acquisition time was only used as a dependent measure for the acquisition task.

Response Time. A dependent measure for both primary and secondary recall tasks, response time was defined as the time interval between subject initiated presentation of a stimuli and the subject's termination of the trial (correlated with the subjects verbalization of the identity of the representation). The response time parameter was tracked and captured by the software. The main program used an internal timing loop accurate to 1/256th of a second. However, the actual time recorded was constrained to 100th of seconds.

Response Errors. Response errors was utilized as a dependent measure in both the primary and secondary recall tasks. Operationally, a response error was defined as a mismatch between a subject's verbal response of a representation and the correct designation as defined in the acquisition task. For example, a subject may have indicated that the textual command "DX" was the representation for "delete paragraph" when it was defined in the acquisition task as the representation for "delete line".

Secondary Analyses

As evidenced by the literature review, little directly relevant research exists on which to base decisions regarding specific a priori comparisons, therefore secondary analysis necessarily relied on post hoc analyses. As detailed in the accompanying series of experimental hypotheses, this deficiency did not restrict the ability to put forth and test specific hypotheses. Additionally, as the major objective of the study was to investigate the general performance characteristics of the competing interface technologies (icon, text and mixed), it would be inappropriate to limit the detailed examination to a limited set of a priori comparisons. Similarly, it would be equally inappropriate to specify all possible experimental combinations a priori.

Due to the ability to define and control experimental error and simplicity of application, as well as general acceptance of the model, the Newman-Keuls test method was utilized to make all possible comparisons among means.

Experimental Hypotheses

Formulated on the findings reported in works examined while conducting the literature review, the following experimental hypotheses are put forth:

1) Presentation format (icon, text, mixed) will affect average acquisition time.

2) Presentation format (icon, text, mixed) will affect average primary recall response time.

3) Presentation format (icon, text, mixed) will affect average secondary recall response time.

4) Presentation format (icon, text, mixed) will affect average primary recall response errors.

5) Presentation format (icon, text, mixed) will affect average secondary recall response errors.

6) Presentation format (icon, text, mixed) will affect average preference ratings.

7) Setblock (basic, enhanced) will affect average acquisition time.

8) Setblock (basic, enhanced) will affect average primary recall response time.

9) Setblock (basic, enhanced) will affect average secondary recall response time.

10) Setblock (basic, enhanced) will affect average primary recall response errors.

11) Setblock (basic, enhanced) will affect average secondary recall response errors.

12) Setblock (basic, enhanced) will affect average preference ratings.

13) Experience (low, medium, high) will affect average acquisition time.

14) Experience (low, medium, high) will affect average primary recall response time.

15) Experience (low, medium, high) will affect average secondary recall response time.

16) Experience (low, medium, high) will affect average primary recall response errors.

17) Experience (low, medium, high) will affect average secondary recall response errors.

18) Experience (low, medium, high) will affect average preference ratings.

19) Session (primary, secondary) will affect average response time.

20) Session (primary, secondary) will affect average response errors.

Results

Subject Experience

In an attempt to establish a link between typing ability and the experience classification criteria, a standard typing test was completed by each subject. The criteria utilized to assign subjects to an experience category was as follows:

- subjects claiming no experience on both a word processor **and** word processing program were assigned to the low experience condition
- subjects claiming experience on either a word processor **or** word processing experience were assigned to the medium experience condition
- subjects claiming both word processor experience **and** experience with a word processing program were assigned to the high experience condition.

It is important to note that reported typing experience and ability were not used as criteria for experimental classification, but were examined to determine if they represented meaningful measures for subsequent efforts.

Table 5 indicates the average, minimum and maximum experience claimed by subjects. The table is organized around the experience categories as defined above. For subjects assigned to the low experience category, the average number of months typing experience was 69, with a minimum of no experience using a typewriter to a maximum of 300 months (25 years) experience. For subjects assigned to the medium experience category, the average typing experience was 70 months, with 1 and 240 months (20 years) reported as the minimum and maximum lengths of experience respectively. Similarly, the average reported typing experience for subjects assigned to the high experience category

Table 5. Subject Typing Characteristics by Experience

	Months Typing Experience	Actual wpm	Typing Test Corrected wpm	Percent Accuracy
Low				
Average	69	18	2.1	95
Minimum	0	6	0	89
Maximum	300	41	18	100
Medium				
Average	70	26	2.4	96
Minimum	1	14	0	94
Maximum	240	41	14	99
High				
Average	141	35	1.6	96
Minimum	10	16	0	93
Maximum	384	66	7	98

was 141 months, with the minimum and maximum values as 10 and 384 months (32 years) respectively.

Table 5 also indicates the results of the typing test as a function of experience category. The typing test utilized was a commercial product (Typing Tutor III) which provided actual words per minute (wpm), corrected wpm, and percent accuracy. The scores reported in Table 5 reflect the average, minimum and maximums scores across all subjects. Therefore, in all likelihood, the three scores do not represent a single subject. Rather they indicate the median and range of each score. Actual words per minute indicates the rate at which subjects typed (including errors). The corrected words per minute reflects the actual words per minute minus a penalty for errors. The accuracy rating reflects the ratio of correct keystrokes to total keystrokes expressed as a percentage.

Table 6 details reported subject experience for word processors as a function of experience category or classification. As subjects classified into the low category did not possess experience with either a word processor or word processing packages (by definition), they are not included in the table.

The average number of word processors used by medium experience category subjects was .5, with the minimum and maximum number of word processors reported as 0 and two respectively. The medium experience category criteria allowed for a subject to have practical applied experience with either a word processor or a word processing package. Therefore, the minimum for number of word processors is zero.

Other data collected indicate the word processing usage characteristics of subjects. Specifically, subjects were requested to list for each word processor (if any) the: number of months experience, the average frequency per week, and the average duration (in minutes) per use. These figures were combined into a single measure (total claimed experience) and expressed in hrs. which is also presented in Table 6. The average usage for word

Table 6. Subject Word Processor Usage Characteristics by Experience Classification

	Number of Word Processors	Usage (months)	Frequency (per/week)	Duration (min./use)	Total Claimed Experience U*F*D (hr.s)
Medium					
Average	.5	9.1	3.9	64.	13.62
Minimum	0.	0.	0.	0.	0.
Maximum	2.	36.	24.	360.	84.
High					
Average	1.5	9.62	2.62	132.	12.59
Minimum	1.	1.	1.	30.	30.
Maximum	6.	36.	5.	480.	80.

processors in the medium experience category was 9.1 months, with the corresponding value for the high experience group 9.62 months. The medium experience subjects reported using a word processor 3.9 times per week, while high experience subjects reported using word processors an average of 2.62 times per week. The average duration of use (minutes) for the medium experience group was slightly over an hour (64 minutes), while the high experience group reported using word processing approximately twice as long (132 minutes).

The parallel measures for word processing programs are detailed in Table 7. The average number of word processing programs reported by the medium experience group was 2, while the high experience group reported a slightly wider range of experience with an average 2.3 word processing packages. The minimum number of word processing packages for the medium experience group was once again zero, with the high experience group reporting a minimum of one. The corresponding maximum number of word processing packages used by medium experience subjects was seven, while the high experience subjects indicated a maximum of five. The medium experience subject on the average reported using a package an average of 4.3 times per week for approximately an hour and a half (88 minutes), for a year. The high experience subject reported on the average, using a word processing package an average of 5.7 times for slightly more than an hour (64 minutes) for the past 12 months.

Acquisition Time

A three-way mixed factors analysis of variance with acquisition time as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high) and setblock (basic, enhanced) significantly affect the time required to acquire word processing functions. The resulting ANOVA summary table is presented as Table 8.

Table 7. Subject Word Processing Program Usage Characteristics by Experience Classification

	Number of Programs	Usage (months)	Frequency (per/week)	Duration (min./use)	Total Claimed Experience U*F*D (hr.s)
Medium					
Average	2.	12.	4.3	88.	14.01
Minimum	0.	0.	0.	0.	0.
Maximum	7.	36.	24.	480.	112.
High					
Average	2.3	12.	5.7	64.	20.48
Minimum	1.	1.	1.	10.	.05
Maximum	5.	36.	25.	300.	210.

Table 8. ANOVA Summary Table: Acquisition Time as Dependent Measure

Source	SS	df	MS	F
Between Subjects	988.9832	29		
Experience	18.6985	2	9.3493	.2602
Subjects W/I Group	970.2847	27	35.9365	
Within Subjects	122.7884	150		
Format	31.7546	2	15.8773	14.3898**
Experience*Format	1.0747	4	.2686	.2435
Format*S W/I Group	59.5821	54	1.1034	
Setblock	.1411	1	.1411	.3242
Experience*Setblock	.1149	2	.0575	.1320
Setblock*S W/I Group	11.7539	27	.4353	
Format*Setblock	.8664	2	.4332	1.3956
Experience*Format*Setblock	.7384	4	.1846	.5947
Format*Setblock*S W/I Group	16.7624	54	.3104	
Total	1111.77	179		

* Significant at the .05 level
** Significant at the .01 level

As detailed in Table 8, significance ($p < .01$) was obtained for the main effect of format. Thus, indicating that acquisition time was dependent or influenced by the presentation format of commands. No other effects were found to be significant.

The results of a Newman-Keuls test (Table 9) indicate that the significant differences are between: the text (3.817 seconds) and the icon formats (4.502 seconds), and the text and mixed (4.822 seconds) conditions. The analyses support the hypothesis that format significantly influences the time to acquire representations. More specifically, it can be stated that subjects required significantly less time to acquire text representations than either the icon or mixed formats. These results are depicted graphically in Figure 3. As indicated by the Newman-Keuls test, the differences between the averaged acquisition times of the icon and mixed conditions were not large enough to be considered significantly different.

Primary Recall Response Time

A three-way mixed factors analysis of variance with primary recall response time as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high) and setblock (basic, enhanced) significantly affects the time required to recall word processing functions. The resulting ANOVA summary table is presented as Table 10.

The ANOVA supports the hypotheses that presentation format affects average primary response time ($p < .01$) and setblock ($p < .01$). Additionally, Table 10 demonstrates that the interaction of the main effects of format and setblock achieve significance ($p < .01$). Newman-Keuls tests were conducted for the format effect and the interaction of format and setblock, but not for the main effect of setblock. Setblock has only two levels, and the Newman-Keuls test is conducted where comparisons are to be made between three or more means. Therefore, no Newman-Keuls table is provided for the significant setblock condition.

Table 9. Newman - Keuls Test: Acquisition Response Time - Format

		TEXT 3.817	ICON 4.502	MIXED 4.822	0.01	0.05
TEXT	3.817		.685†	1.006†	.510	.384
ICON	4.502			.320	.580	.463
MIXED	4.822					

* Significant at the .05 level
† Significant at the .01 level

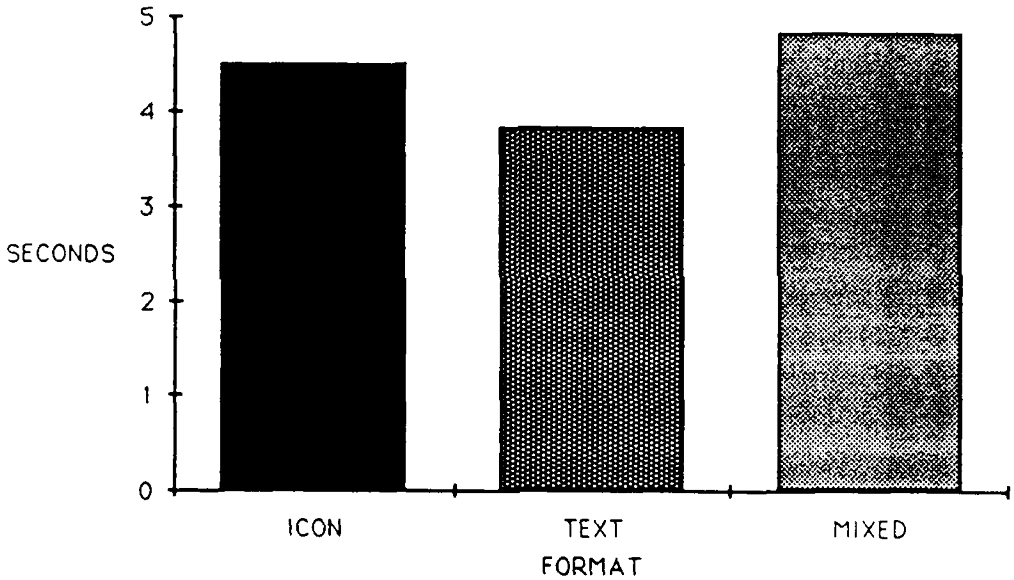


FIGURE 3. AVERAGE ACQUISITION RESPONSE TIME - FORMAT

Table 10. ANOVA Summary Table: Primary Recall Response Time as Dependent Measure

Source	SS	df	MS	F
Between Subjects	332.660	29		
Experience	32.494	2	16.247	1.461
Subjects W/I Group	300.166	27	11.117	
Within Subjects	3382.735	150		
Format	57.174	2	28.587	16.757**
Experience*Format	4.896	4	1.224	.717
Format*S W/I Group	92.14	54	1.706	
Setblock	45.175	1	45.175	24.080**
Experience*Setblock	9.594	2	4.797	2.557
Setblock*S W/I Group	50.645	27	1.876	
Format*Setblock	58.121	2	29.061	25.031**
Experience*Format*Setblock	2.271	4	.568	.489
Format*Setblock*S W/I Group	62.719	54	1.161	
Total	715.295	179		

* Significant at the .05 level
** Significant at the .01 level

Table 11 indicates that the difference in average response times of mixed (2.405 seconds) and icon (3.742 seconds) conditions is large enough to be considered significant. Similarly, the difference in average response times of text (2.777 seconds) and icon (3.742 seconds) is significant.

In the primary recall task, subjects responded significantly faster to mixed stimuli than to the iconic representations of word processing functions. Similarly, on the average, subjects responded faster to the text representations than to icon stimuli. The difference in response latency between the mixed (2.405 seconds) and text (2.777 seconds) conditions was not large enough to be considered meaningful.

The findings of the ANOVA and Newman-Keuls tests are represented in Figure 4, which graphically depicts the average primary recall response times as a function of format.

Table 10 also indicates that the average primary recall response time is affected by the main effect of setblock. As detailed above, setblock has two levels, basic and enhanced. Therefore, any significance achieved in an ANOVA can be attributed to the difference in the two means. The hypothesis that setblock influences average primary recall response time is supported. Figure 5 demonstrates that the average response time for the enhanced stimuli was shorter.

Table 10 indicates that the interaction of the main effects, format and setblock, was significant. In context of the present study, some combination(s) of setblock and format resulted in significantly different average response times than others. A Newman-Keuls test was conducted to determine which mean(s) differed significantly. The results depicted in Table 12 indicate that text - enhanced average primary recall response time, differs significantly from the average primary recall response times achieved for any of the remaining conditions. Specifically, the text - enhanced response time (1.505 seconds) was significantly shorter when compared to the mixed - enhanced (2.092 seconds), mixed -

Table 11. Newman - Keuls Test: Primary Recall Response Time - Format

		MIXED 2.405	TEXT 2.777	ICON 3.742	0.01	0.05
MIXED	2.405		.372	1.337†	.634	.477
TEXT	2.777			.965†	.722	.573
ICON	3.742					

* Significant at the .05 level
† Significant at the .01 level

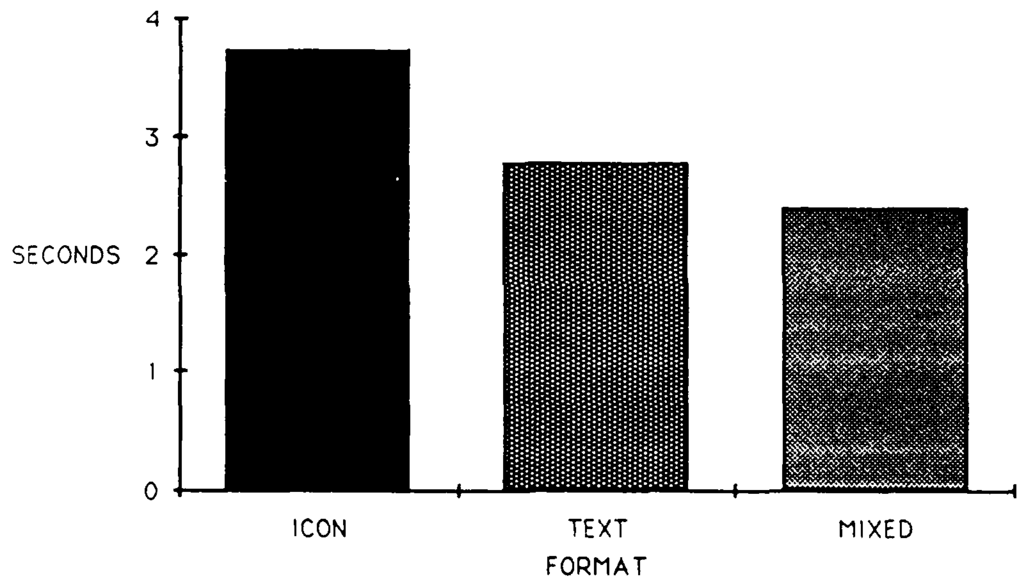


FIGURE 4. AVERAGE PRIMARY RECALL RESPONSE TIME - FORMAT

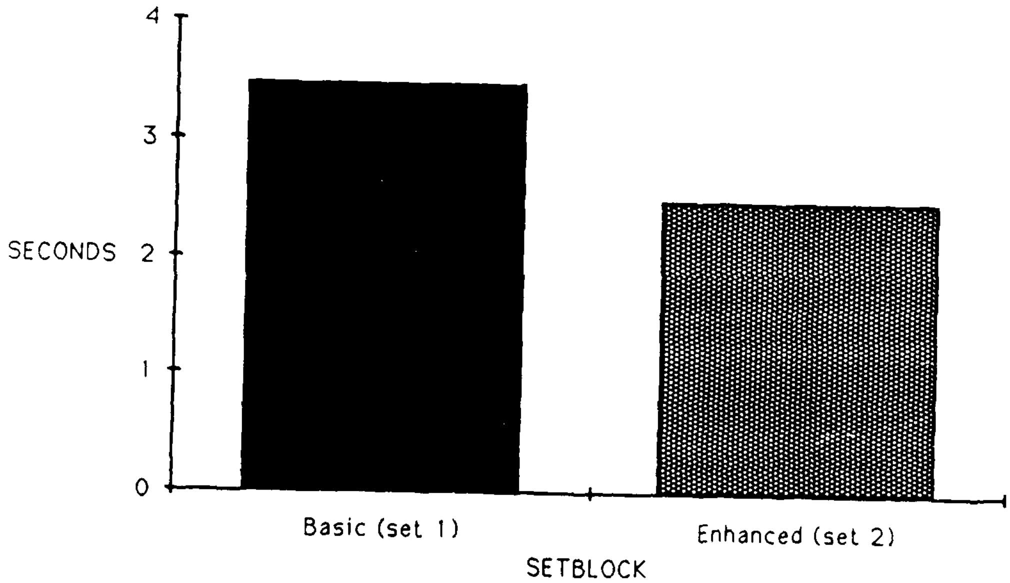


FIGURE 5. AVERAGE PRIMARY RECALL RESPONSE TIME - SETBLOCK

Table 12. Newman - Keuls Test: Primary Recall Response Time - Format by Setblock

		TEXT 2	MIXED 2	MIXED 1	ICON 1	ICON 2	TEXT 1	0.01	0.05
		1.505	2.092	2.718	3.661	3.824	4.049		
TEXT 2	1.505		0.587†	1.213†	2.156†	2.319†	2.544†	0.601	0.501
MIXED 2	2.092			0.626†	1.569†	1.732†	1.957†	0.580	0.479
MIXED 1	2.718				0.943†	1.106†	1.331†	0.553	0.450
ICON 1	3.661					0.163	0.388	0.515	0.409
ICON 2	3.824						0.225	0.453	0.341
TEXT 1	4.049								

* Significant at the .05 level
† Significant at the .01 level

basic (2.718 seconds), icon - basic (3.661 seconds), icon - enhanced (3.824 seconds), and text - basic (4.049 seconds) conditions. Similarly, when comparing the mixed - enhanced response time (2.092 seconds) to all other conditions the differences achieved was significant. That is, subjects responded significantly faster to the mixed - enhanced (2.092 seconds) condition than to all other combinations except the text - enhanced (1.505 seconds) condition. The mixed - basic (2.718 seconds) condition was determined to result in significantly shorter average response times when compared to the icon - basic (3.661 seconds), icon - enhanced (3.824 seconds), and text - basic (4.049 seconds) conditions. Comparisons between the means of the remaining experimental conditions resulted in insignificant differences. Figure 6 depicts the average primary recall format by setblock response times graphically.

Primary Recall Response Errors

A three-way mixed factors analysis of variance with percent correct primary recall responses as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high) and setblock (basic, enhanced) significantly affect the number of immediate recall errors (percent correct) made while attempting to identify the various representations of select word processing functions. The resulting ANOVA summary table is presented as Table 13. As the ANOVA procedure was developed for continuous distributions, the simple frequency of correct or incorrect responses could not be utilized. Therefore, before being subjected to analysis, the raw response data was transformed into a continuous percentage correct format and are reported as such.

Similarly, to the average primary recall response time, Table 13 indicates that format, setblock and the interaction of the two main effects produce significant ($p < .01$) average

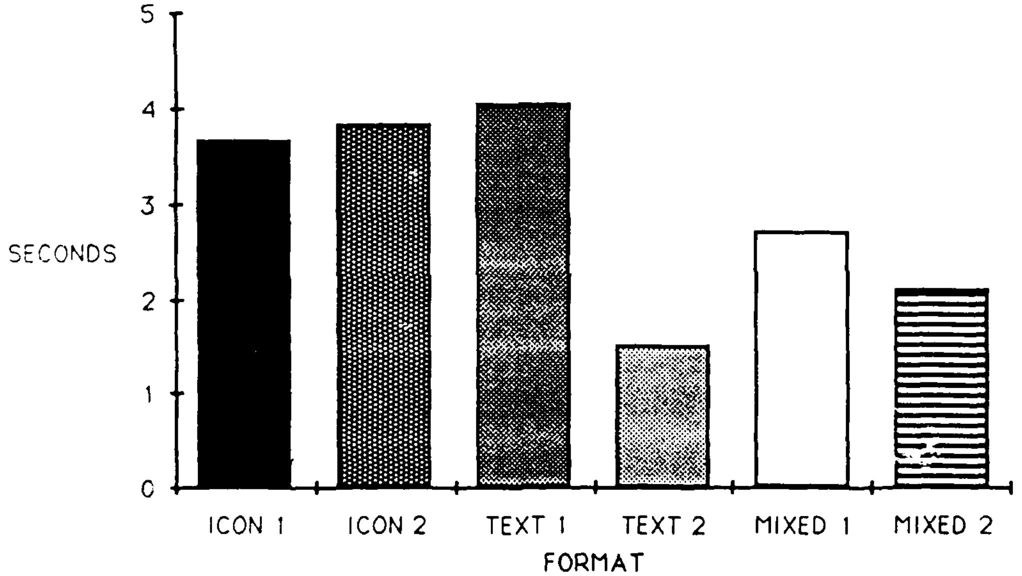


FIGURE 6. AVERAGE PRIMARY RECALL RESPONSE TIME - FORMAT BY SETBLOCK

Table 13. ANOVA Summary Table: Primary Recall Response Errors as Dependent Measure

Source	SS	df	MS	F
Between Subjects	5400.476	29		
Experience	595.895	2	297.948	1.674
Subjects W/I Group	4804.581	27	177.947	
Within Subjects	12367.555	150		
Format	4716.809	2	2358.405	35.265**
Experience*Format	229.084	4	57.271	.856
Format*S W/I Group	3611.378	54	66.877	
Setblock	609.876	1	609.875	18.183**
Experience*Setblock	252.776	2	126.388	3.768*
Setblock*S W/I Group	905.597	27	33.541	
Format*Setblock	718.473	2	359.237	15.134**
Experience*Format*Setblock	41.749	4	10.437	.440
Format*Setblock*S W/I Group	1281.813	54	23.737	
Total	17768.031	179		

* Significant at the .05 level
** Significant at the .01 level

differences in terms of response errors. Therefore, the hypothesis that format and setblock significantly affect the number of response errors is supported.

Additionally, Table 13 indicates that the interaction of experience and setblock significantly ($p < .05$) affect the number of response errors.

Newman-Keuls tests were conducted to determine which formats affect response errors significantly, and which combination(s) of format and setblock result in significantly different average percent correct primary recall responses. As related above, it was not necessary to conduct a Newman-Keuls test for the main effect of setblock to determine which comparisons result in significantly different mean percent correct responses, therefore, no table is provided. A Newman-Keuls test was conducted to determine which combination(s) of experience and setblock resulted in significantly different average primary recall percent correct responses. The results of these tests are reported in Table 14, Table 15 and Table 16.

Table 14 indicates a significant difference in terms of average percent correct responses was achieved between the icon (86.140% correct) and text (95.263% correct) formats, and the icon (86.140% correct) and mixed (98.158% correct) formats. On the average, subjects made a larger number of errors (reported as percent correct) when identifying iconic representations of word processing representations than in either the text or mixed formats. The difference in average number of correct responses between the text and mixed formats was not large enough to be considered meaningfully different. Examination of Figure 7 average primary recall correct response by format, supports these conclusions.

While a Newman-Keuls test was not performed, significant differences were achieved in terms of the number of percent correctly identified representations as a function of setblock. Specifically, the difference between the percent correct responses of basic

Table 14. Newman - Keuls Test: Primary Recall Percent Correct Responses - Format

		ICON	TEXT	MIXED	0.01	0.05
		86.140	95.263	98.158		
ICON	86.140		9.123†	12.018†	4.519	3.590
TEXT	95.263			2.895	3.970	2.988
MIXED	98.158					

* Significant at the .05 level
† Significant at the .01 level

Table 15. Newman - Keuls Test: Primary Recall Percent Correct Responses - Experience by Setblock

		E1 SET1	E1 SET2	E2 SET1	E3 SET1	E2 SET2	E3 SET2	0.01	0.05
		80.526	82.632	90.000	98.421	99.474	99.474		
E1 SET1	80.526		2.105	9.474†	17.895†	18.947†	18.947†	5.276	4.399
E1 SET2	82.632			7.368†	15.790†	16.842†	16.842†	5.097	4.208
E2 SET1	90.000				8.421†	9.474†	9.474†	4.853	3.955
E3 SET1	98.421					1.053	1.053	4.526	3.595
E2 SET2	99.474						0.000	3.976	2.992
E3 SET2	99.474								

* Significant at the .05 level
† Significant at the .01 level

Table 16. Newman - Keuls Test: Primary Recall Percent Correct Responses - Format by Setblock

		ICON 2 85.965	ICON 1 86.318	TEXT 1 90.702	MIXED 1 97.018	MIXED 2 99.298	TEXT 2 99.825	0.01	0.05
ICON 2	85.965		0.353	4.737†	11.053†	13.333†	13.860†	4.439	3.700
ICON 1	86.318			4.384†	10.700†	12.980†	13.507†	4.287	3.540
TEXT 1	90.702				6.316†	8.596†	9.123†	4.083	3.327
MIXED 1	97.018					2.281	2.807	3.807	3.024
MIXED 2	99.298						0.526	3.345	2.517
TEXT 2	99.825								

* Significant at the .05 level
† Significant at the .01 level

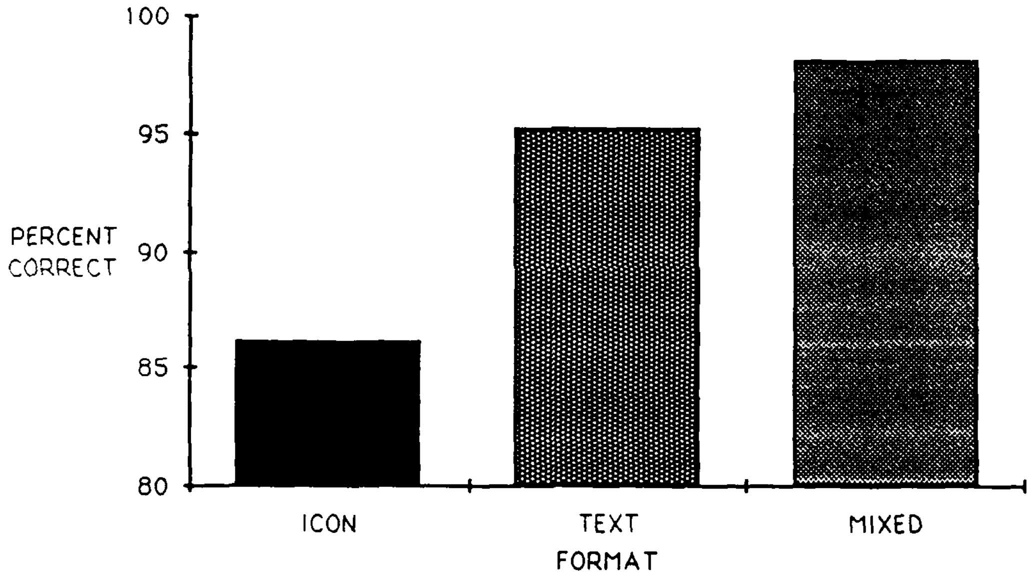


FIGURE 7. AVERAGE PRIMARY RECALL PERCENT CORRECT RESPONSES - FORMAT

(91.345% correct) and the percent correct responses of enhanced (95.030% correct) stimuli was determined to be significant. This difference is graphically depicted in Figure 8.

Review of Table 15 indicates that specific combinations of experience and setblock significantly interact to affect how subjects perform in correctly identifying word processing representations. As would be expected, the results of the Newman-Keuls test indicate that the low experience group identifying basic stimuli performed (80.526% correct) significantly less well than all combinations of the more experienced subjects. Specifically, low experience subjects identifying basic word processing representations made significantly more errors (80.526% correct) than medium experience subjects identifying either basic (90.00% correct) or enhanced (99.474% correct) representations. Similarly, low experience subjects identifying basic representations made significantly more errors (80.526% correct) than did high experience subjects identifying either basic (98.421% correct) or enhanced (99.474% correct) word processing representations.

Similarly, low experience subjects evaluating enhanced representations made significantly more identification errors (82.632% correct) than did either the medium or high experience subjects identifying basic (90.000% correct) or enhanced (99.474% correct) word processing representations. Significant differences in terms of percent correct responses was obtained between the medium experience subjects identifying basic (90.000% correct) representations and their performance evaluating enhanced (99.474% correct) representations, as well as their performance compared with high experience subjects evaluating either basic set (98.421% correct) or enhanced (99.474% correct) stimuli. These results are graphically depicted in Figure 9.

Examination of Table 16 indicates that specific combination(s) of format and setblock achieved significant differences in the percent correct responses. Subjects correctly identified both variants of the text (90.702% and 99.825% correct for basic and enhanced

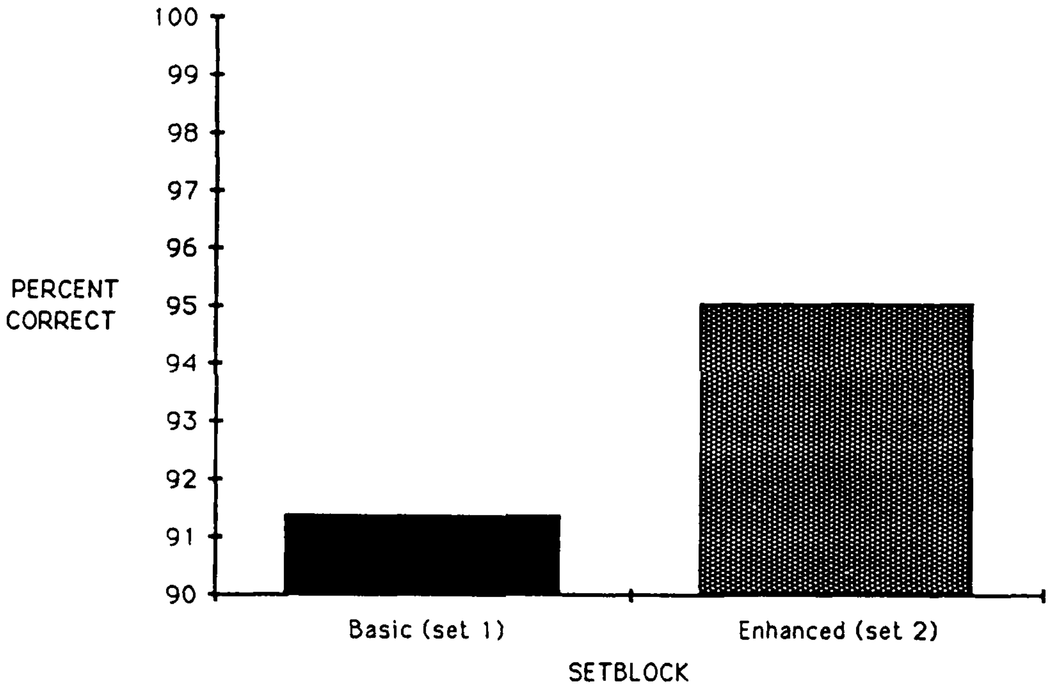


FIGURE 8. AVERAGE PERCENT CORRECT PRIMARY RECALL RESPONSES - SETBLOCK

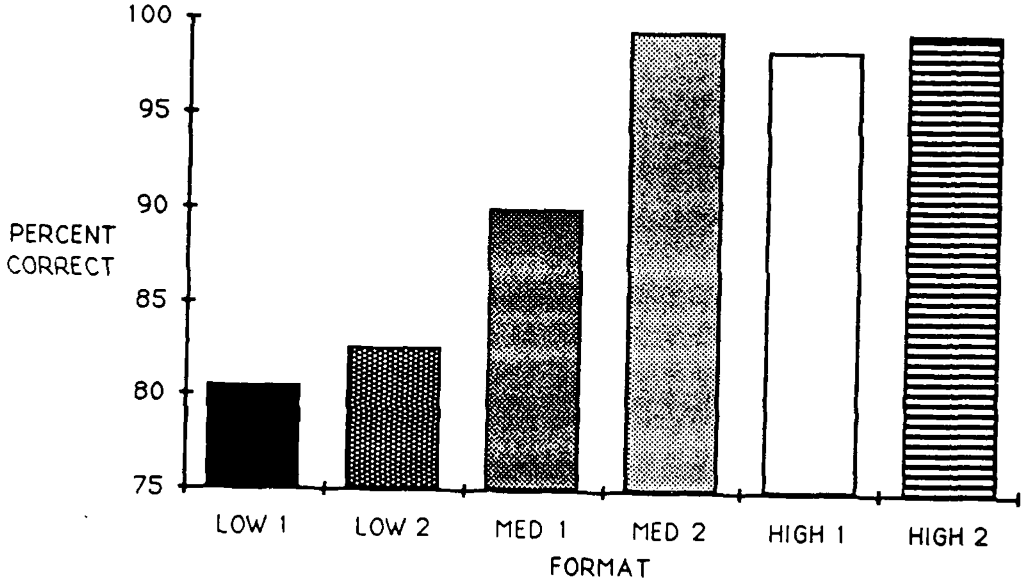


FIGURE 9. AVERAGE PRIMARY RECALL PERCENT CORRECT RESPONSES - EXPERIENCE BY SETBLOCK

sets respectively) and mixed (97.018% and 99.298% correct for basic and enhanced sets respectively) representations significantly more frequently than either of the icon (85.965% and 86.318% correct for basic and enhanced sets respectively) conditions. Comparison of the text - basic (90.702% correct) condition with both mixed (97.018% and 99.298% correct for basic and enhanced sets respectively) conditions and the text - enhanced (99.825% correct) format also achieved significance. Specifically, the text - basic (90.702% correct) condition was correctly identified less frequently than the other three conditions. These results are depicted in Figure 10.

Secondary Recall Response Time

A three-way mixed factors analysis of variance with secondary recall response time as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high) and setblock (basic, enhanced) significantly affect the time required to provide the designation of select word processing function representations after a one week interval. The resulting ANOVA summary table is presented as Table 17.

Comparison of the ANOVA summary tables for both response time and errors for primary and secondary tasks indicate that in general, the effects that held significance in the primary recall tasks also achieved (or perhaps more correctly maintained) significance in the secondary recall task (actual F ratio values differed, but similar significant main and interactive effects were achieved).

As indicated, examination of Table 17 depicts significant effects of format ($p < .01$), setblock ($p < .01$), and significant interaction between format and setblock ($p < .01$). This analysis supports the hypotheses that average secondary recall response time is influenced by format and setblock.

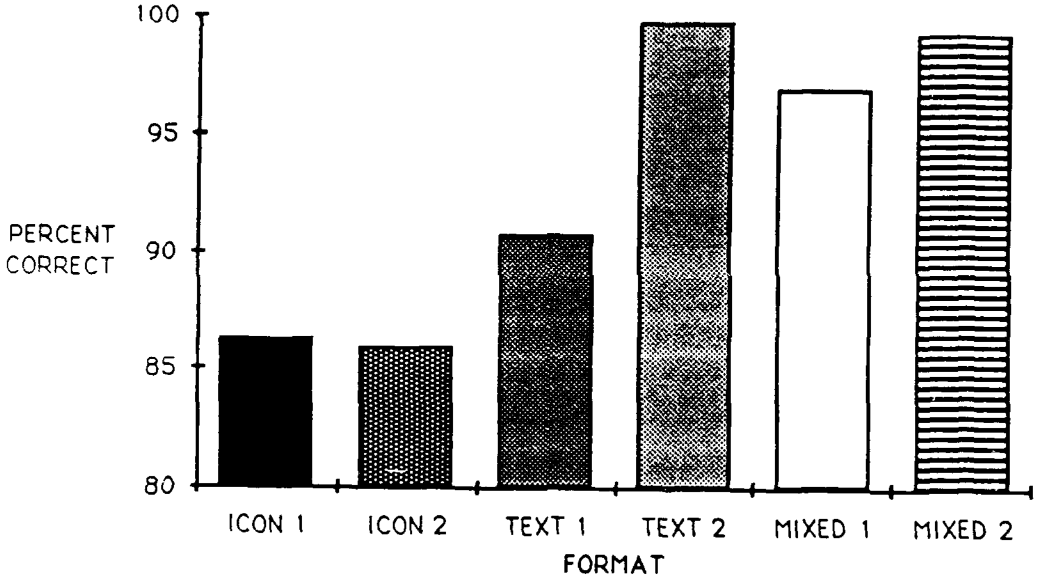


FIGURE 10. AVERAGE PRIMARY RECALL PERCENT CORRECT RESPONSES - FORMAT BY SETBLOCK

Table 17. ANOVA Summary Table: Secondary Recall Response Time as Dependent Measure

Source	SS	df	MS	F
Between Subjects	289.172	29		
Experience	41.563	2	20.782	2.266
Subjects W/I Group	247.609	27	9.171	
Within Subjects	240.874	150		
Format	63.958	2	31.979	32.786**
Experience*Format	3.325	4	.831	.852
Format*S W/I Group	52.674	54	.9754	
Setblock	39.232	1	39.232	33.417**
Experience*Setblock	1.740	2	.870	.741
Setblock*S W/I Group	31.688	27	1.174	
Format*Setblock	22.919	2	11.459	26.35**
Experience*Format*Setblock	1.854	4	.463	1.065
Format*Setblock*S W/I Group	23.484	54	.435	
Total	530.046	179		

* Significant at the .05 level
** Significant at the .01 level

To determine which combination(s) of factors significantly differ, a series of Newman-Keuls tests were conducted. Specifically, tests were conducted for the main effect of format, and the interaction of format and setblock. A Newman-Keuls test was not conducted for the main effect of setblock. The results of the Newman-Keuls tests for format, and the format by setblock interaction are provided in Tables 18 and 19 respectively.

Table 18 indicates significant differences between the average secondary recall response time of mixed (2.533 seconds) and iconic (3.801 seconds) word processing representations. Similarly, a significant difference exists between the average secondary recall response time for text (2.541 seconds) and icon (3.801 seconds) representations. On the average, subjects responded faster to the mixed and text representations than they did to iconic representations of the same word processing functions. These values are graphically depicted in Figure 11.

As significance for the main effect of setblock was demonstrated in the ANOVA (Table 17), and setblock has only two levels, the significance can be attributed directly to the difference between the average response time for basic (3.430 seconds) and enhanced (2.492). Therefore no post hoc test was conducted. On the average, enhanced representations were identified faster than basic. The average response times are depicted graphically in Figure 12.

Table 19 details the results of the Newman-Keuls test for average secondary recall response time task format by setblock interaction. The average text - enhanced response time (1.592 seconds) was significantly shorter when compared to any of the following combinations: mixed - enhanced (2.176 seconds); mixed - basic (2.890 seconds); text - basic (3.489 seconds); icon - enhanced (3.706 seconds); icon - basic (3.896 seconds). In turn, the average mixed - enhanced condition was significantly faster (2.176 seconds)

Table 18. Newman - Keuls Test: Secondary Recall Response Time - Format

		MIXED 2.533	TEXT 2.541	ICON 3.801	0.01	0.05
MIXED	2.533		.008	1.268†	.479	.361
TEXT	2.541			1.261†	.546	.434
ICON	3.801					

* Significant at the .05 level
† Significant at the .01 level

Table 19. Newman - Keuls Test: Secondary Recall Response Time - Format by Setblock

		TEXT 2	MIXED 2	MIXED 1	TEXT 1	ICON 2	ICON 1	0.01	0.05
TEXT 2	1.592	1.592	2.176	2.890	3.489	3.706	3.896		
MIXED 2	2.176		0.583†	1.298†	1.897†	2.114†	2.304†	0.601	0.501
MIXED 1	2.890			0.714†	1.313†	1.530†	1.721†	0.580	0.479
TEXT 1	3.489				0.599†	0.816†	1.006†	0.553	0.450
ICON 2	3.706					0.217	0.408	0.515	0.409
ICON 1	3.896						0.190	0.453	0.341

* Significant at the .05 level
† Significant at the .01 level

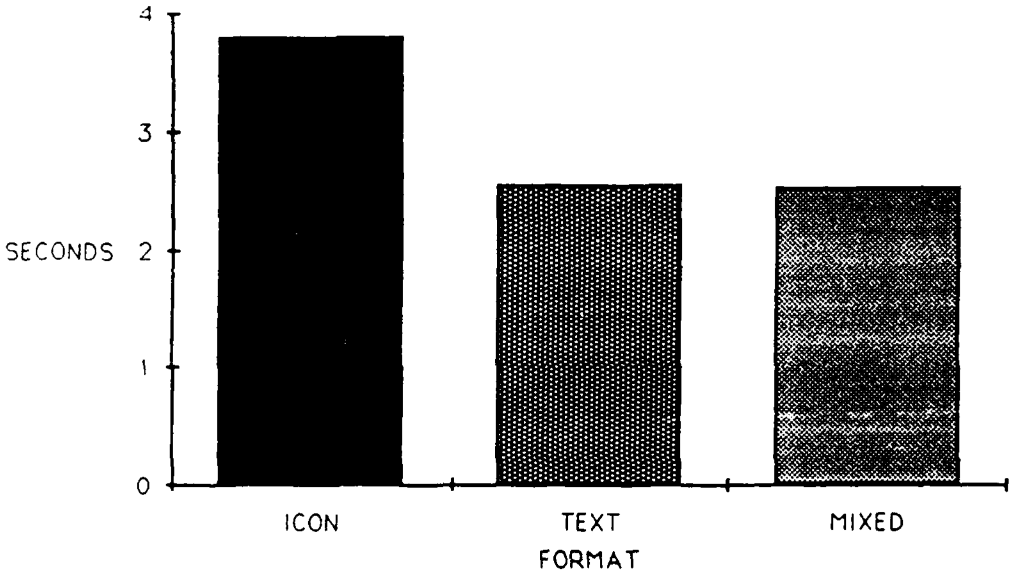


FIGURE 11 AVERAGE SECONDARY RECALL RESPONSE TIME - FORMAT

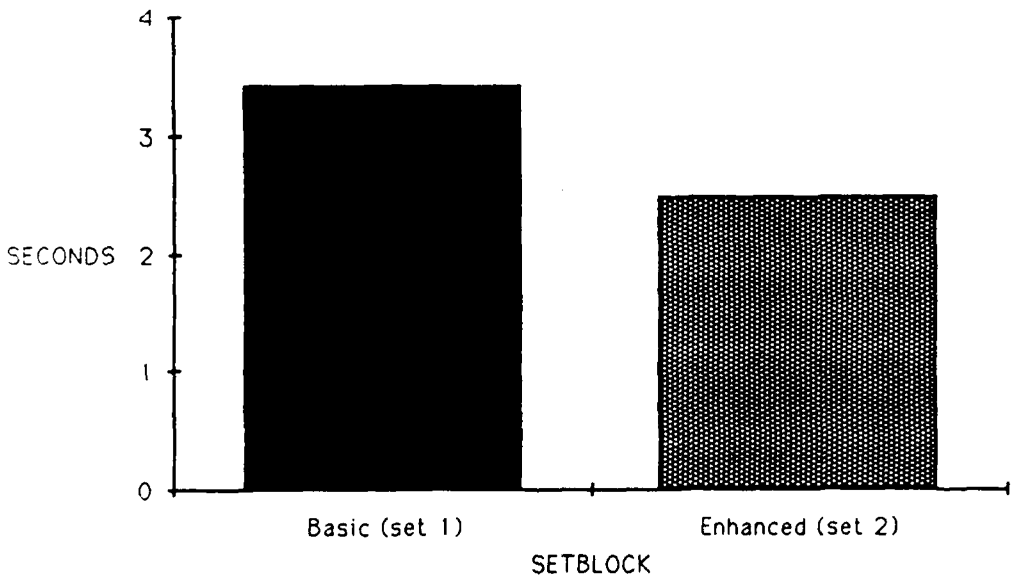


FIGURE 12. AVERAGE SECONDARY RECALL RESPONSE TIME - SETBLOCK

when compared to the average: mixed - basic (2.890 seconds); text - basic (3.489 seconds); icon - enhanced (3.706 seconds) and icon - basic (3.896 seconds) conditions. Finally, the average mixed - basic condition was determined significantly faster (2.890 seconds); when compared to the average: text - basic (3.489 seconds); icon - enhanced (3.706 seconds) and icon - basic (3.896 seconds) conditions. These results are graphically depicted in Figure 13.

Secondary Recall Response Errors

A three-way mixed factors analysis of variance with secondary recall percent correct responses as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high) and setblock (basic, enhanced) significantly affect the number of errors (percent correct) made while identifying designations of select word processing function representations after a one week interval. The resulting ANOVA summary table is presented as Table 20.

As indicated above, the ANOVA procedure was developed for analysis of continuous data, therefore, before being subjected to analysis, the raw response data (response errors) was transformed into a percent correct format.

Also as indicated above, the significance achieved in the secondary recall ANOVAs follows those of the primary recall task ANOVAs. Specifically, significance was achieved for the main effects of format ($p < .01$), and setblock ($p < .01$), and for the interaction of experience and setblock ($p < .05$). Finally, the format by setblock interaction was determined to be significant ($p < .01$). The results support the hypothesis that the number of secondary recall percent correct responses is affected by format and setblock.

To determine which combination of factors and/or levels contributed to the significance achieved, a series of Newman-Keuls multiple comparison tests were conducted. Specifically, the post hoc test procedure was applied to the average percentage

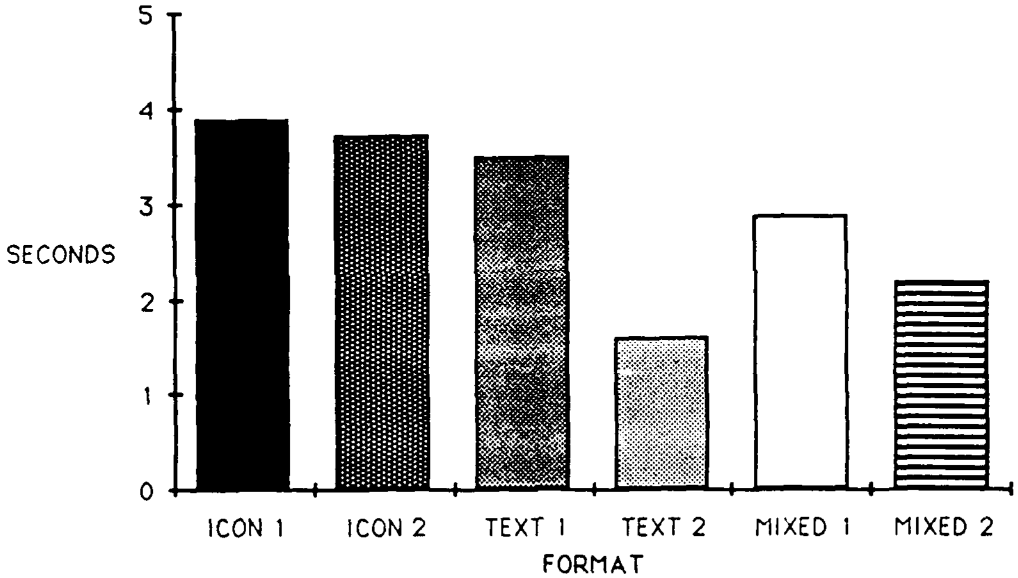


FIGURE 13. AVERAGE SECONDARY RECALL RESPONSE TIME - FORMAT BY SETBLOCK

Table 20. ANOVA Summary Table: Secondary Recall Response Errors as Dependent Measure

Source	SS	df	MS	F
Between Subjects	5251.023	29		
Experience	378.908	2	189.454	1.0499
Subjects W/I Group	4872.115	27	180.445	
Within Subjects	17539.243	150		
Format	8556.194	2	4278.097	44.821**
Experience*Format	241.590	4	60.398	.633
Format*S W/I Group	5154.201	54	95.448	
Setblock	369.500	1	369.500	11.637**
Experience*Setblock	264.387	2	132.194	4.163*
Setblock*S W/I Group	857.341	27	31.753	
Format*Setblock	707.600	2	353.800	14.994**
Experience*Format*Setblock	114.206	4	28.551	1.210
Format*Setblock*S W/I Group	1274.223	54	23.597	
Total	22790.2656	179		

* Significant at the .05 level
** Significant at the .01 level

correct responses as determined for format, and as determined for the interaction of experience and setblock, and finally to the average percent correct responses as a function of format and setblock. A Newman-Keuls test was not required for the main effect of setblock because it has only two levels, and any significance achieved in an ANOVA can be directly attributed to the difference between the two means (all comparisons have by definition, been made). The results of the Newman-Keuls tests are depicted in Table 21, Table 22, and Table 23.

Table 21 contains the results of the Newman-Keuls test conducted to determine the significant differences between format averages. Accordingly, the difference of average correct responses achieved between the icon (82.193% correct) and text (95.965% correct) formats were significant. Similarly, the difference of average correct responses achieved between the icon (82.193% correct) and mixed (97.544% correct) formats are also deemed significant. The difference between the average percent correct text (95.965% correct) and mixed (97.544% correct) formats are not large enough to be considered significant. The average correct responses achieved are graphically depicted in Figure 14.

While a Newman-Keuls test procedure was not conducted, significant differences were achieved in terms of the number of percent correctly identified representations as a function of setblock. Specifically, the difference between the percent correct responses of basic (90.468% correct) and the percent correct responses of enhanced (93.333% correct) stimuli was determined to be significant. This difference is graphically depicted in Figure 15.

The Newman-Keuls post hoc test for secondary percent correct recall responses as determined for the interaction of experience and setblock indicate that, not surprisingly, the low experience group performed the least well in terms of correctly identifying word processing functions. These results are found in Table 22 Specifically, the low experience

Table 21. Newman - Keuls Test: Secondary Recall Percent Correct Responses - Format

		ICON 82.193	TEXT 95.965	MIXED 97.544	0.01	0.05
ICON	82.193		13.772†	15.351†	5.398	4.288
TEXT	95.965			1.579	4.742	3.569
MIXED	97.544					

* Significant at the .05 level
† Significant at the .01 level

Table 22. Newman - Keuls Test: Secondary Recall Percent Correct Responses - Experience by Setblock

		E1 SET1	E1 SET2	E2 SET1	E3 SET1	E2 SET2	E3 SET2	0.01	0.05
		77.368	80.526	91.579	97.368	100.000	100.000		
E1 SET1	77.368		3.158*	14.211†	20.000†	22.632†	22.632†	6.287	4.280
E1 SET2	80.526			11.053†	16.842†	19.474†	19.474†	6.073	4.094
E2 SET1	91.579				5.789†	8.421†	8.421†	5.783	3.848
E3 SET1	97.368					2.632	2.632	5.393	3.498
E2 SET2	100.000						0.000	4.738	2.912
E3 SET2	100.000								

* Significant at the .05 level
† Significant at the .01 level

Table 23. Newman - Keuls Test: Secondary Recall Percent Correct Responses - Format by Setblock

		ICON 2	ICON 1	TEXT 1	MIXED 1	MIXED 2	TEXT 2	0.01	0.05
		81.053	83.333	92.281	95.790	99.298	99.649		
ICON 2	81.053		2.281	11.228†	14.737†	18.246†	18.597†	4.426	3.689
ICON 1	83.333			8.947†	12.456†	15.965†	16.316†	4.275	3.530
TEXT 1	92.281				3.509†	7.018†	7.368†	4.071	3.317
MIXED 1	95.790					3.509†	3.860†	3.796	3.015
MIXED 2	99.298						0.351	3.335	2.510
TEXT 2	99.649								

* Significant at the .05 level
† Significant at the .01 level

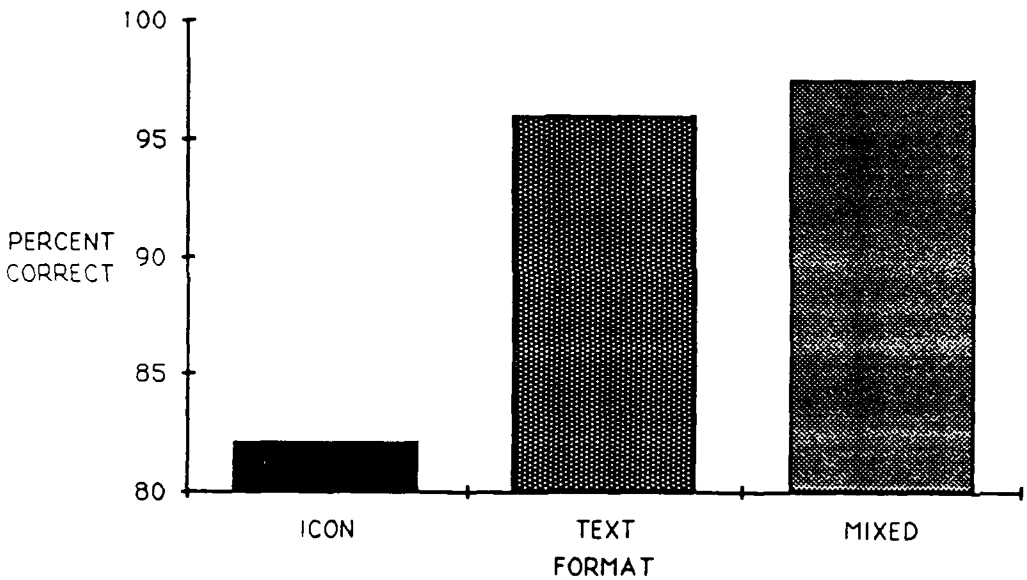


FIGURE 14. AVERAGE SECONDARY RECALL CORRECT RESPONSES - FORMAT

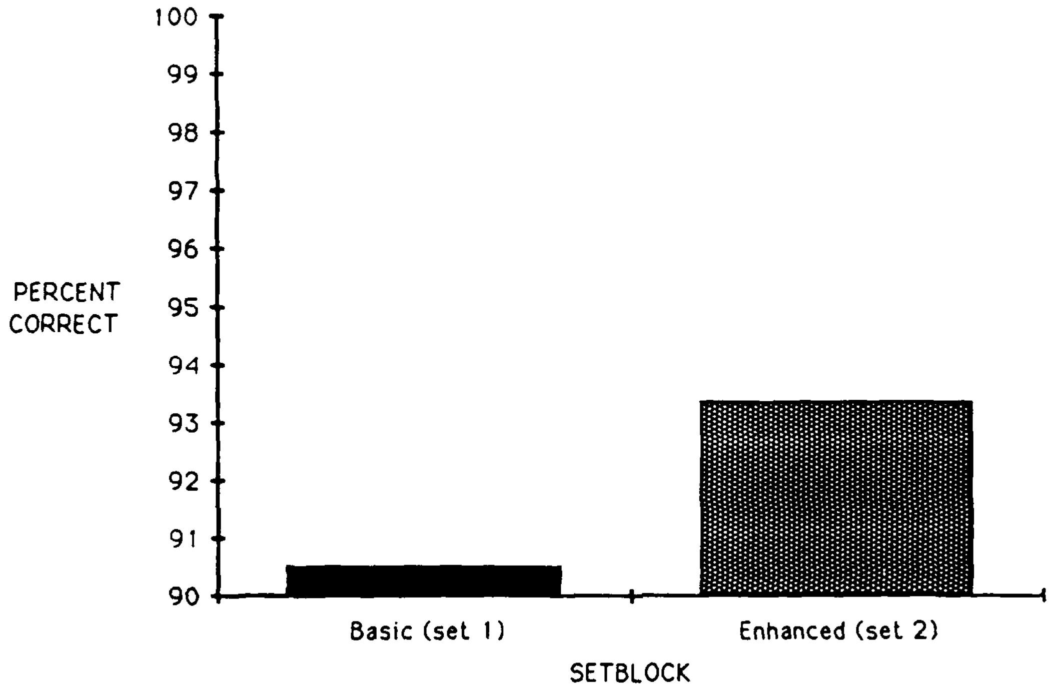


FIGURE 15. AVERAGE PERCENT CORRECT SECONDARY RECALL RESPONSES- SETBLOCK

group performed significantly ($p < .05$) poorer than either the medium and high experience level groups for either basic or enhanced stimuli. Additionally, low experience subjects on the average, correctly identified significantly fewer enhanced representations (80.526% correct) when compared to the performance of the medium experience subjects basic (91.579% correct) or enhanced (100.000% correct) performance; and high experience subjects identifying basic (97.368% correct) and enhanced (100.00% correct) stimuli. The average performance of the medium experience subjects identifying basic (91.579% correct) stimuli was significantly different from the performance they achieved in identifying enhanced (100.000% correct) representations, and the high experience subjects identifying either basic (97.368% correct) or enhanced (100.000% correct). The results are graphically depicted in Figure 16.

The results of the Newman-Keuls post hoc test for secondary percent correct recall responses as determined for the format by setblock interaction are presented in Table 23. The analysis indicates that with the exception of the comparison between the percent correct responses for icon - basic (83.333% correct) with icon - enhanced (81.053% correct); and the comparison between the mixed - enhanced (99.298% correct) and text - enhanced (99.649% correct) conditions, the differences between all other means was significant ($p < .01$).

Comparing either icon - basic (83.333% correct) or icon - enhanced (81.053% correct) with either text - basic (92.281% correct) or text - enhanced (99.649% correct), and either mixed - basic (95.790% correct) and mixed enhanced (99.298% correct), indicate that the icon representations were correctly identified significantly ($p <.01$) less often. Significant differences in percent correct responses were also achieved by comparing text - basic (92.281% correct) to the mixed - basic (95.790% correct), mixed - enhanced (99.298% correct) and text - enhanced (99.649% correct) means. Significant

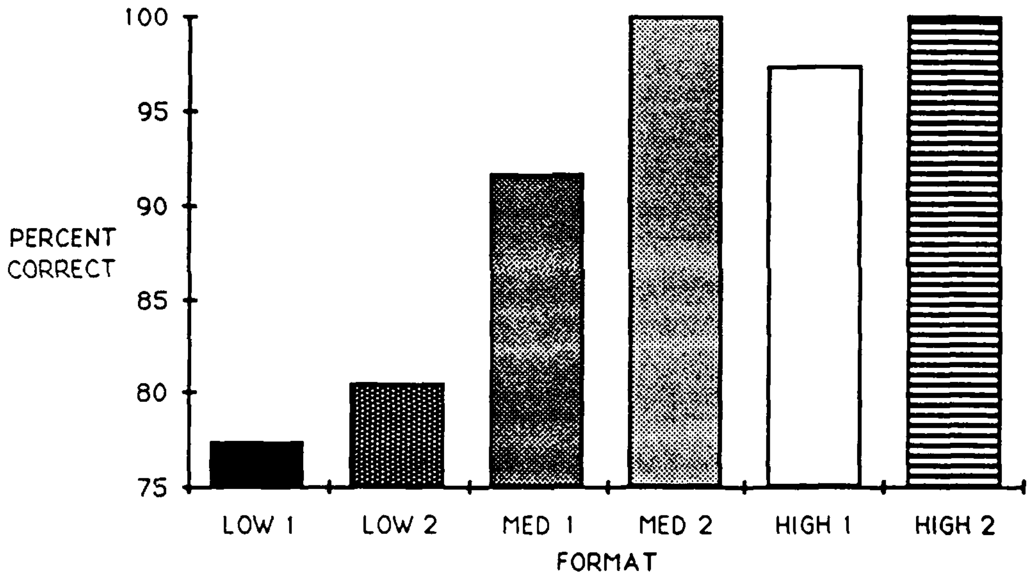


FIGURE 16. AVERAGE SECONDARY RECALL PERCENT CORRECT RESPONSES - EXPERIENCE BY SETBLOCK

differences were demonstrated when comparing average percent correct mixed - basic (95.790% correct) responses with average mixed - enhanced (99.298% correct) and text - enhanced (99.649%) correct responses. The results are depicted in Figure 17.

Combined Recall Response Time

A four-way mixed factors analysis of variance with recall response time as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high), setblock (basic, enhanced) and session (primary, secondary) significantly affect the time required to recall the designation of select word processing function representations. The resulting ANOVA summary table is presented as Table 24.

As indicated in Table 24, significant effects were achieved for format ($p < .01$), setblock ($p < .01$), interaction between format and setblock ($p < .01$), and the format by setblock by session interaction ($p < .05$). The analysis supports the hypotheses that response time is influenced by format, setblock and session.

To determine which combination(s) of factors significantly differ, Newman-Keuls tests were conducted. Specifically, tests were conducted for the main effect of format, format by setblock interaction, and format by setblock by session interaction. A Newman-Keuls test was not conducted for the main effect of setblock, and therefore no table is provided. The results of the Newman-Keuls tests for format, format by setblock interaction, and three-way format by setblock by session interaction are provided in Table 25, Table 26 and Table 27 respectively.

The Newman-Keuls test for format indicates that comparison of the combined response times (primary and secondary recall tasks) for the mixed (2.469 seconds) and icon (3.772 seconds) formats are significantly ($p < .01$) different. Similarly, the difference between the combined response times of text (2.659 seconds) and icon (3.772 seconds)

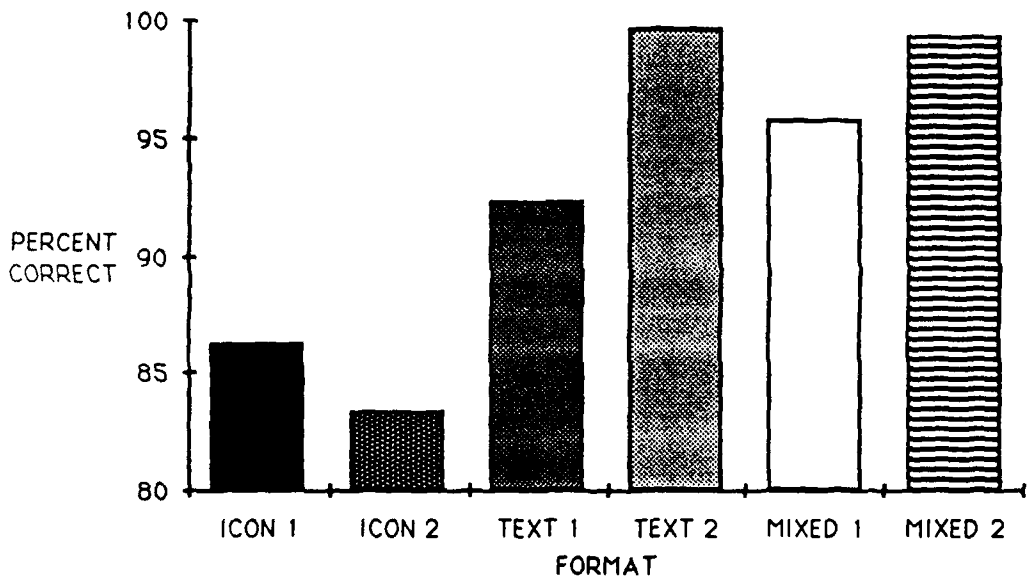


FIGURE 17. AVERAGE SECONDARY RECALL PERCENT CORRECT RESPONSES - FORMAT BY SETBLOCK

Table 24. ANOVA Summary Table: Combined Response Times as Dependent Measure

Source	SS	df	MS	F
Between Subjects	531.656	29		
Experience	71.625	2	35.812	2.102
Subjects W/I Group	460.031	27	17.038	
Within Subjects	697.102	330		
Format	118.885	2	59.442	32.305**
Experience*Format	3.945	4	.986	.536
Format*S W/I Group	99.369	54	1.840	
Setblock	84.303	1	84.303	43.954**
Experience*Setblock	9.669	2	4.834	2.520
Setblock*S W/I Group	51.796	27	1.918	
Session	.024	1	.024	.007
Experience*Session	2.433	2	1.216	.374
Session*S W/I Group	87.744	27	3.250	
Format*Setblock	77.012	2	38.506	38.429**
Experience*Format*Setblock	3.414	4	.854	.852
Format*Setblock*S W/I Group	54.085	54	1.002	
Format*Session	2.247	2	1.123	1.333
Experience*Format*Session	4.276	4	1.069	1.269
Format*Session*S W/I Group	45.493	54	.842	

Table 24 (cont). ANOVA Summary Table: Combined Response Times as Dependent Measure

Source	SS	df	MS	F
Setblock*Session	.105	1	.105	.206
Experience*Setblock*Session	1.665	2	.832	1.631
Setblock*Session*S W/I Group	13.78	27	.510	
Format*Setblock*Session	4.028	2	2.014	3.385*
Experience*Format*Setblock*Session	.710	4	.178	.299
Format*Setblock*Session*S W/I Group	32.119	54	.595	
Total	1228.758	359		

* Significant at the .05 level
** Significant at the .01 level

Table 25. Newman - Keuls Test: Combined Recall Response Time - Format

		MIXED 2.469	TEXT 2.659	ICON 3.772	0.01	0.05
MIXED	2.469		.190	1.303†	.465	.350
TEXT	2.659			1.113†	.530	.421
ICON	3.772					

* Significant at the .05 level
† Significant at the .01 level

Table 26. Newman - Keuls Test: Combined Recall Response Time - Format by Setblock

		TEXT 2	MIXED 2	MIXED 1	ICON 2	TEXT 1	ICON 1	0.01	0.05
		1.549	2.134	2.804	3.765	3.769	3.779		
TEXT 2	1.549		0.585†	1.255†	2.216†	2.220†	2.230†	0.645	0.538
MIXED 2	2.134			0.670†	1.631†	1.635†	1.645†	0.623	0.514
MIXED 1	2.804				0.961†	0.965†	0.975†	0.593	0.483
ICON 2	3.765					0.004	0.014	0.553	0.440
TEXT 1	3.769						0.010	0.486	0.366
ICON 1	3.779								

* Significant at the .05 level
† Significant at the .01 level

Table 27. Newman - Keuls Test: Combined Response Time - Format by Setblock by Session

	P(T2)	S(T2)	P(M2)	S(M2)	P(M1)	S(M1)	S(T1)	P(I1)	S(I2)	P(I2)	S(I1)	P(T1)	.01	.05
	1.505	1.592	2.092	2.176	2.718	2.890	3.489	3.661	3.706	3.824	3.896	4.048		
P(T2)		0.087	0.587*	0.671†	1.213†	1.385†	1.984	†2.155†	2.201†	2.319†	2.391†	2.543†	.811	.690
S(T2)			0.500*	0.583*	1.126†	1.298†	1.897†	2.068†	2.114†	2.231†	2.304†	2.456†	.779	.666
P(M2)				0.084	0.626†	0.798†	1.397†	1.569†	1.614†	1.732†	1.805†	1.957†	.768	.655
S(M2)					0.542	0.714†	1.313†	1.485†	1.530†	1.648†	1.721†	1.873†	.755	.641
P(M1)						0.172	0.771†	0.943†	0.988†	1.106†	1.178†	1.330†	.739	.625
S(M1)							0.599†	0.770†	0.816†	0.934†	1.006†	1.158†	.722	.607
S(T1)								0.172	0.217	0.335	0.408	0.560	.703	.586
P(I1)									0.046	0.163	0.236	0.388	.679	.561
S(I2)										0.118	0.190	0.342	.646	.527
P(I2)											0.073	0.225	.603	.479
S(I1)												0.152	.530	.399
P(T1)														

* Significant at the .05 level
† Significant at the .01 level

formats is also significant ($p < .01$). The difference between the average combined response time for mixed (2.469 seconds) and text (2.659 seconds) is too small to be considered meaningful (Figure 18).

While a Newman-Keuls test was not conducted on the average response time as a function of setblock, the ANOVA test indicates that the difference between the two means is significant ($p < .01$). The average combined response time for basic was 3.450 seconds while the average response time for enhanced was 2.483 seconds (Figure 19).

Table 26 lists all the comparisons between the various format by setblock means. The average combined response time for text - enhanced (1.549 seconds) when compared with the all other means was determined to be significant ($p < .01$). The average combined response time for the text - enhanced (1.549) combination was determined to be significantly faster than any other format by setblock combination. Similarly, comparison of the average combined response time of the mixed - enhanced response time (2.134 seconds) with all other means was also determined to be significant. In regard to response time, the mixed - enhanced (2.134 seconds) condition was determined to be significantly faster than the mixed - basic (2.804 seconds), icon enhanced (3.765 seconds), text - basic (3.769 seconds), and icon basic (3.779 seconds) conditions. Comparison of the mixed - basic (2.804 seconds) format with all other combinations was determined to be significant. The average combined response time for mixed - basic (2.804 seconds) condition was determined to be significantly faster than the icon enhanced (3.765 seconds), text - basic (3.769 seconds), and icon basic (3.779 seconds) conditions (Figure 20).

Table 27 lists the results of the Newman-Keuls test for determination of the significant comparisons as a function of the three-way format by setblock by session interaction. Comparing the combined average response time of primary text - enhanced (1.505 seconds) with all other combinations produced significant differences except with

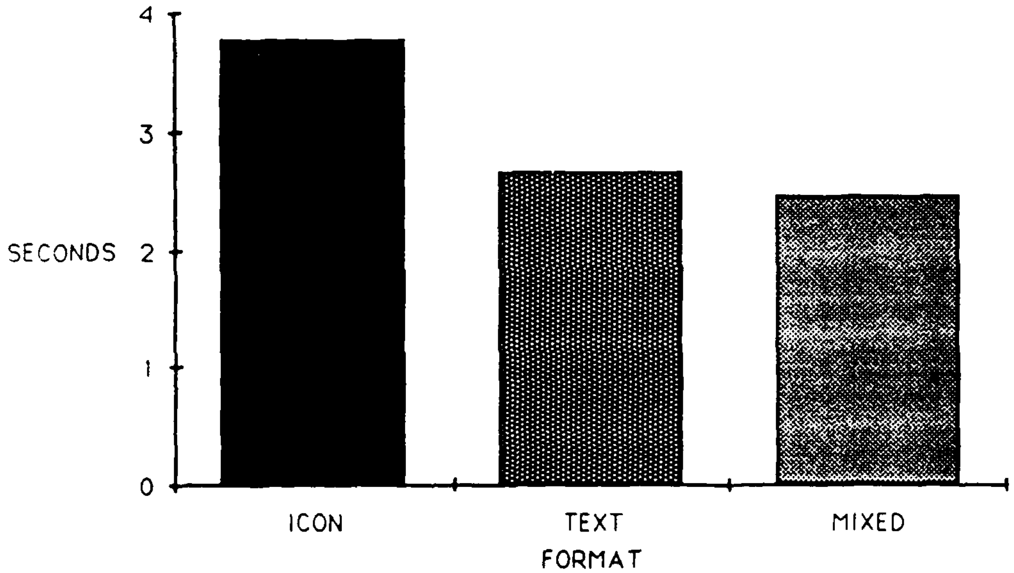


FIGURE 18. AVERAGE COMBINED RECALL RESPONSE TIME - FORMAT

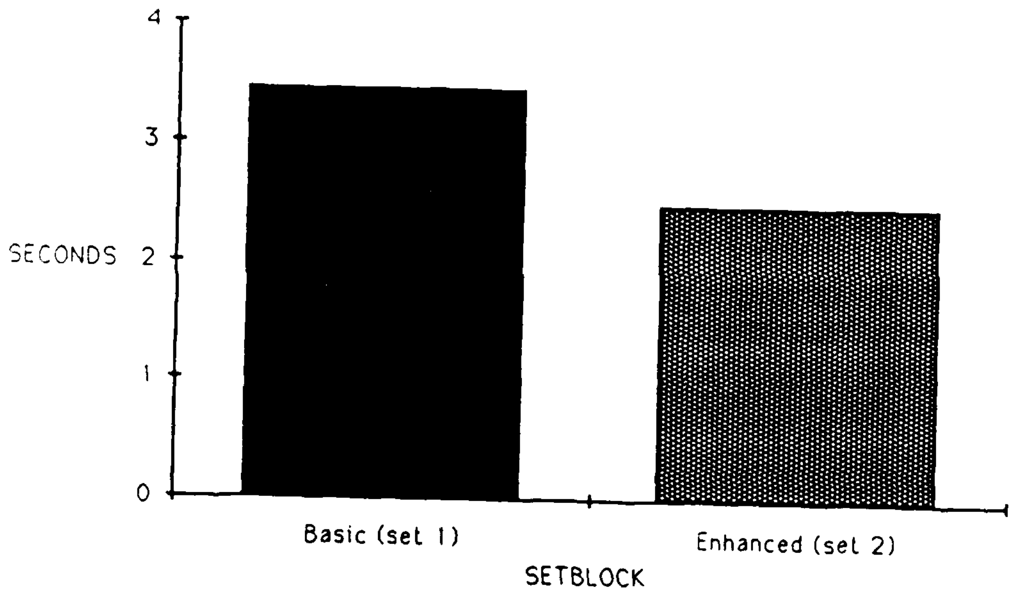


FIGURE 19. AVERAGE COMBINED RECALL RESPONSE TIME - SETBLOCK

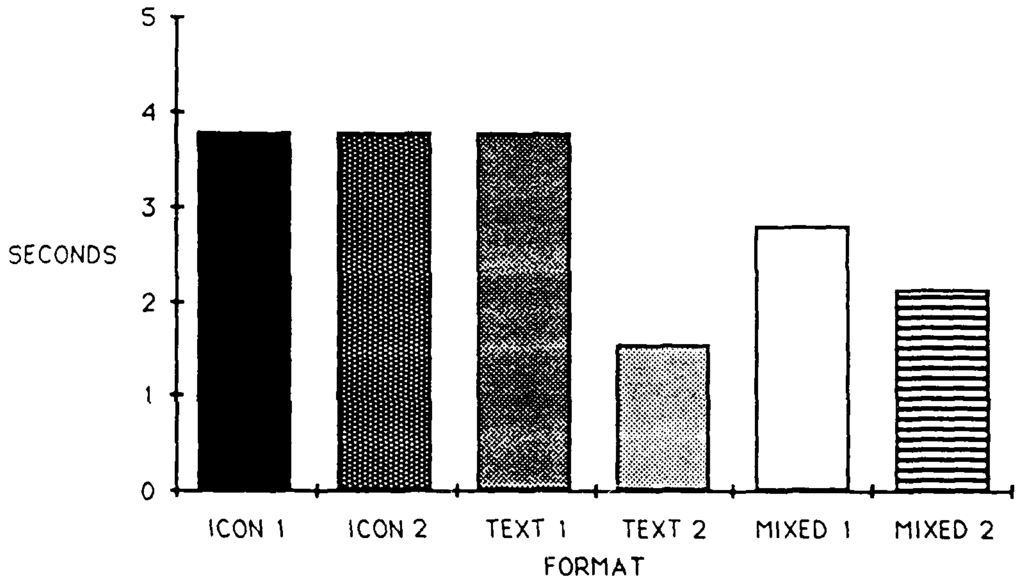


FIGURE 20. AVERAGE COMBINED RECALL RESPONSE TIME - FORMAT BY SETBLOCK

the secondary text - enhanced (1.592 seconds) condition. The average primary text - enhanced (1.505 seconds) response time was determined to be significantly faster than the: primary mixed - enhanced (2.092 seconds). Similarly, primary text - enhanced (1.505 seconds) response time was significantly ($p < .05$) faster than the secondary mixed - enhanced (2.176 seconds), primary mixed - basic (2.718 seconds), secondary mixed - basic (2.890 seconds), secondary text - basic (3.489 seconds), primary icon - basic (3.661 seconds), secondary icon - enhanced (3.706 seconds), primary icon - enhanced (3.824 seconds), secondary icon - basic (3.896 seconds), primary text - basic (4.048 seconds) conditions.

Secondary text - enhanced (1.592 seconds) was significantly faster than all response times except the primary text - enhanced (1.505 seconds) format. Differences between the Secondary text - enhanced (1.592 seconds) and the primary mixed - enhanced (2.092 seconds), as well as the secondary mixed - enhanced (2.176 seconds) formats were considered significant at the .05 level. The secondary text - enhanced (1.592 seconds) was significantly faster than the primary mixed - basic (2.718 seconds), secondary mixed - basic (2.890 seconds), secondary text - basic (3.489 seconds), primary icon - basic (3.661 seconds), secondary icon - enhanced (3.706 seconds), primary icon - enhanced (3.824 seconds), secondary icon - basic (3.896 seconds) and primary text - basic (4.048 seconds) conditions. The average response time of primary mixed - enhanced (2.092 seconds) was determined to be significantly ($p < .01$) faster than the: primary mixed - basic (2.718 seconds), secondary mixed - basic (2.890 seconds), secondary text - basic (3.489 seconds), primary icon - basic (3.661 seconds), secondary icon - enhanced (3.706 seconds), primary icon - enhanced (3.824 seconds), secondary icon - basic (3.896 seconds) and primary text - basic (4.048 seconds) conditions.

The average primary mixed - basic response time (2.718 seconds) was determined to be significantly faster than the average secondary text - basic (3.489 seconds), primary icon - basic (3.661 seconds), secondary icon - enhanced (3.706 seconds), primary icon - enhanced (3.824 seconds), secondary icon - basic (3.896 seconds),and primary text - basic (4.048 seconds) response times.

The average secondary mixed - basic response time (2.890 seconds) was determined to be significantly faster than the average secondary text - basic (3.489 seconds), primary icon - basic (3.661 seconds), secondary icon - enhanced (3.706 seconds), primary icon - enhanced (3.824 seconds), secondary icon - basic (3.896 seconds) and primary text - basic (4.048 seconds) response times.

The average response time for each combination of format, setblock and session are detailed in Figure 21.

Combined Recall Response Errors

A four-way mixed factors analysis of variance with secondary recall percent correct responses as the dependent measure was conducted to determine if presentation format (icon, text, mixed), experience (low, medium, high), setblock (basic, enhanced) and session (primary, secondary) significantly affect the number of errors (percent correct) made identifying the designations of select word processing function representations. The resulting ANOVA summary table is presented as Table 28. As with all the response error data, error frequency data was transformed into a percent correct format prior to analysis.

As indicated in Table 28, significant effects were achieved for format ($p < .01$), setblock ($p < .01$), experience by setblock interaction ($p < .01$), and the two-way, format by setblock interaction ($p < .05$). The ANOVA supports the hypotheses that percent correct responses are affected by format, and setblock.

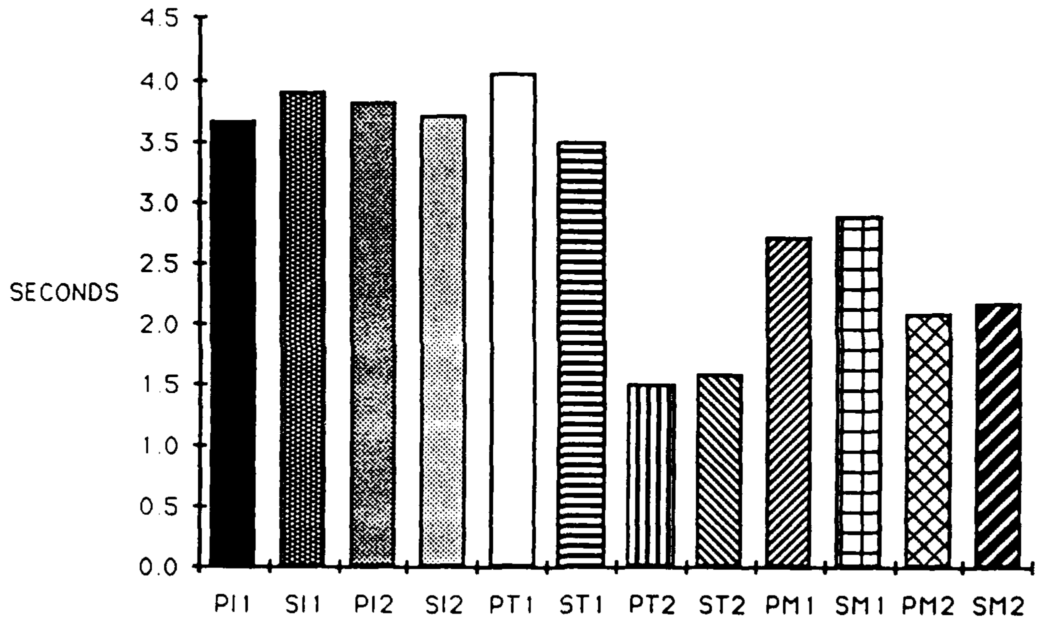


FIGURE 21. AVERAGE COMBINED RECALL RESPONSE TIME - SESSION BY FORMAT BY SETBLOCK

Table 28. ANOVA Summary Table: Combined Response Errors as Dependent Measure

Source	SS	df	MS	F
Between Subjects	9778.394	29		
Experience	901.662	2	450.831	1.371
Subjects W/I Group	8876.732	27	328.768	
Within Subjects	46774.545	330		
Format	12932.131	2	6466.066	77.474**
Experience*Format	385.042	4	96.261	1.153
Format*S W/I Group	4506.926	54	83.462	
Setblock	965.219	1	965.219	22.320**
Experience*Setblock	512.619	2	256.310	5.927**
Setblock*S W/I Group	1167.590	27	43.244	
Session	148.969	1	148.969	.416
Experience*Session	72.176	2	36.088	.100
Session*S W/I Group	9675.9	27	358.367	
Format*Setblock	1377.808	2	688.904	31.123**
Experience*Format*Setblock	100.031	4	25.008	1.129
Format*Setblock*S W/I Group	1195.289	54	22.135	
Format*Session	344.568	2	172.284	1.061
Experience*Format*Session	85.257	4	21.314	.131
Format*Session*S W/I Group	8764.545	54	162.306	

Table 28 (cont). ANOVA Summary Table: Combined Response Errors as Dependent Measure

Source	SS	df	MS	F
Setblock*Session	15.082	1	15.082	.231
Experience*Setblock*Session	3.847	2	1.924	.029
Setblock*Session*S W/I Group	1762.697	27	65.285	
Format*Setblock*Session	47.245	2	23.623	.499
Experience*Format*Setblock*Session	155.740	4	38.935	.823
Format*Setblock*Session*S W/I Group	2555.864	54	47.331	
Total	56552.939	359		

* Significant at the .05 level
** Significant at the .01 level

To determine which combination(s) of factors significantly differ, a Newman-Keuls tests was conducted for each significant F ratio. Specifically, Newman-Keuls comparison tests were conducted for the main effect of format, the experience by setblock interaction, and the two-way format by setblock interaction. For the reasons indicated previously, a Newman-Keuls test was not conducted for the main effect of setblock, and therefore no table is provided. The results of the Newman-Keuls tests are provided in Table 29, Table 30 and Table 31.

The Newman-Keuls test determined the average percent correct responses for the icon format when compared to the average percent correct responses for the text and mixed to be significant. Specifically, subjects correctly identified the proper designation when presented either the text (95.614% correct) or mixed (97.851% correct) representations of word processing functions than when presented the icon (86.167% correct) representations for the same functions. Comparison of the average percent correct responses for the text (95.614% correct) and mixed (97.851% correct) formats were determined not to be significant (Figure 22).

As indicated in Figure 23, subjects correctly identified significantly more enhanced than basic representations.

Table 30 details the findings of the Newman-Keuls multiple comparison test used to determine significant differences as a function of experience and setblock. The test indicates that low experience subjects correctly identified significantly fewer stimuli than all other combinations except when compared against their own performance for enhanced stimuli. The average low experience percent correct responses for either basic (80.526% correct) or enhanced (82.632% correct) with either basic (90.000% correct) or enhanced (99.474% correct) of the medium and/or basic (98.421% correct) and enhanced (99.474% correct) of the high experience groups was determined to be significantly ($p < .01$)

Table 29. Newman - Keuls Test: Combined Recall Percent Correct Responses - Format

		ICON 86.167	TEXT 95.614	MIXED 97.851	0.01	0.05
ICON	86.167		9.447†	11.684†	5.048	4.010
TEXT	95.614			2.237	4.435	3.338
MIXED	97.851					

* Significant at the .05 level
† Significant at the .01 level

Table 30. Newman - Keuls Test: Combined Recall Percent Correct Responses - Experience by Setblock

		E1 SET1 78.947	E1 SET2 81.579	E2 SET1 90.790	E3 SET1 97.895	E2 SET2 99.737	E3 SET2 99.737	0.010	0.05
E1 SET1	78.947		2.632†	11.843†	18.948†	20.790†	20.790†	3.139	3.532
E1 SET2	81.579			9.211†	16.316†	18.158†	18.158†	3.032	3.379
E2 SET1	90.790				7.105†	8.947†	8.947†	2.887	3.176
E3 SET1	97.895					1.842	1.842	2.692	2.887
E2 SET2	99.737						0.000	2.365	2.403
E3 SET2	99.737								

* Significant at the .05 level
† Significant at the .01 level

Table 31. Newman - Keuls Test: Combined Recall Percent Correct Responses - Format by Setblock

		ICON 2	ICON 1	TEXT 1	MIXED 1	MIXED 2	TEXT 2	0.01	0.05
		83.509	84.825	91.491	96.404	99.298	99.737		
ICON 2	83.509		1.316	7.982†	12.895†	15.789†	16.228†	3.031	2.527
ICON 1	84.825			6.667†	11.579†	14.474†	14.912†	2.928	2.417
TEXT 1	91.491				4.912†	7.807†	8.246†	2.788	2.272
MIXED 1	96.404					2.895†	3.333†	2.600	2.065
MIXED 2	99.298						0.439	2.284	1.719
TEXT 2	99.737								

* Significant at the .05 level
† Significant at the .01 level

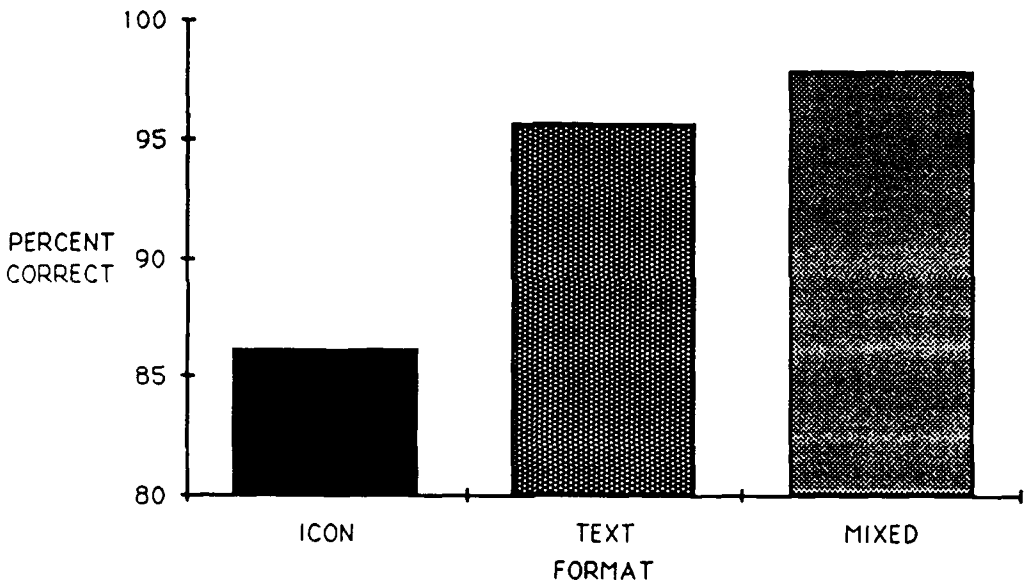


FIGURE 22. AVERAGE COMBINED RECALL PERCENT CORRECT RESPONSES - FORMAT

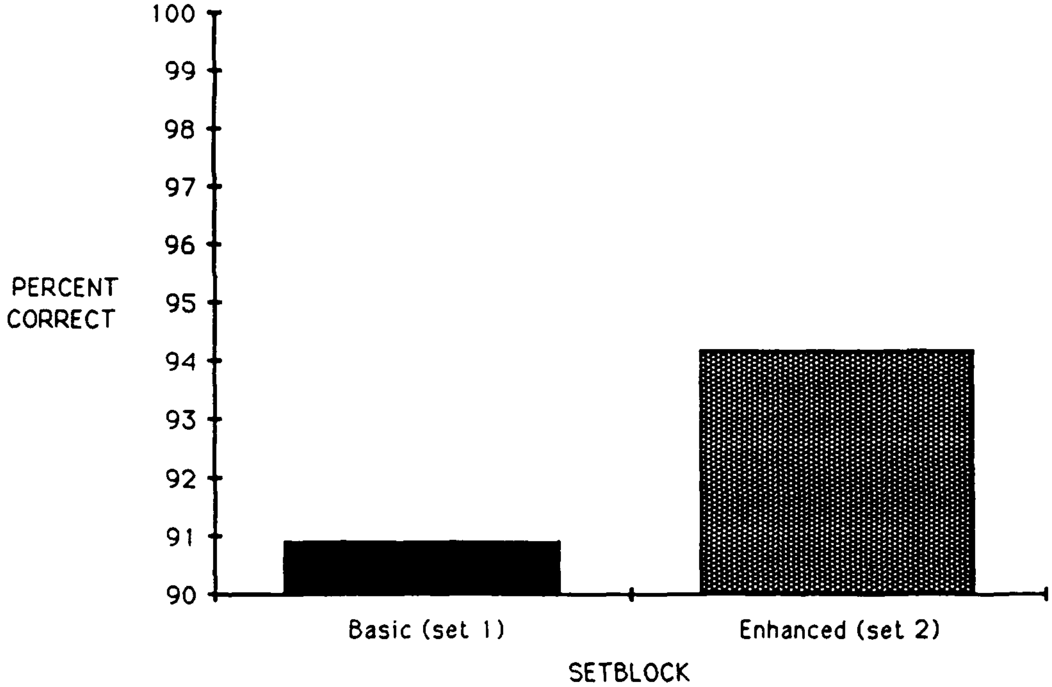


FIGURE 23. AVERAGE PERCENT CORRECT COMBINED RESPONSES - SETBLOCK

different. Differences between the medium experience basic (90.000% correct) and the average high experience basic (98.421% correct), medium experience - enhanced (99.474% correct) and high experience - enhanced (99.474% correct) formats were also determined to be significantly different. The other possible comparisons were determined not to be significant (Figure 24).

Table 31 lists the results of the Newman-Keuls test used to compare the the average percent correct responses as a function of format and setblock. Examination of the table reveals that subjects correctly identified the icon representations significantly less frequently than either the text or mixed representations of the same word processing functions. Comparison of the average percent correct response of either icon basic (83.509% correct) with icon enhanced 84.825% correct) with the average percent correct responses for the text - basic (91.491% correct), mixed - basic (96.404% correct), mixed - enhanced (99.298% correct) and text - enhanced (99.737% correct) conditions were deemed significant ($p <. 01$).

Comparison of the average percent correct responses for the text - basic (91.491% correct) with the mixed - basic (96.404% correct), mixed - enhanced (99.298% correct) and text - enhanced (99.737% correct) indicate that subjects correctly identified significantly fewer text - basic stimuli. Comparison of the mixed - basic (96.404% correct) with the average mixed - enhanced (99.298% correct) or text - enhanced (99.737% correct) indicate that subjects correctly identified significantly fewer of the mixed - basic representations.

The average percentage correct responses are graphically depicted in Figure 25.

Confusion Matrix

As demonstrated by Egan, Bowers and Gomez (1981), development and analysis of a confusion matrix is useful in examining and characterizing response errors of

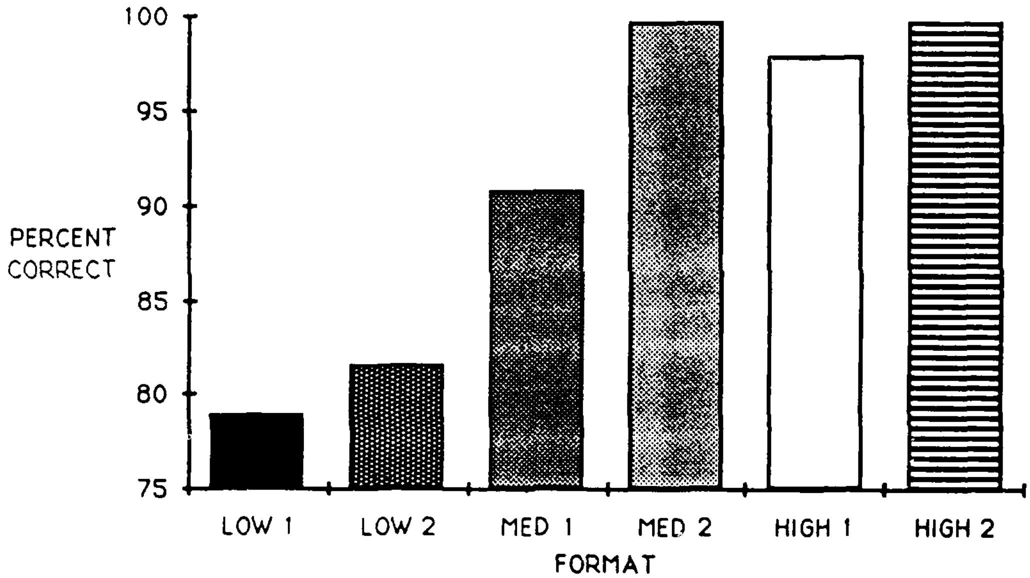


FIGURE 24. AVERAGE COMBINED RECALL PERCENT CORRECT RESPONSES - EXPERIENCE BY SETBLOCK

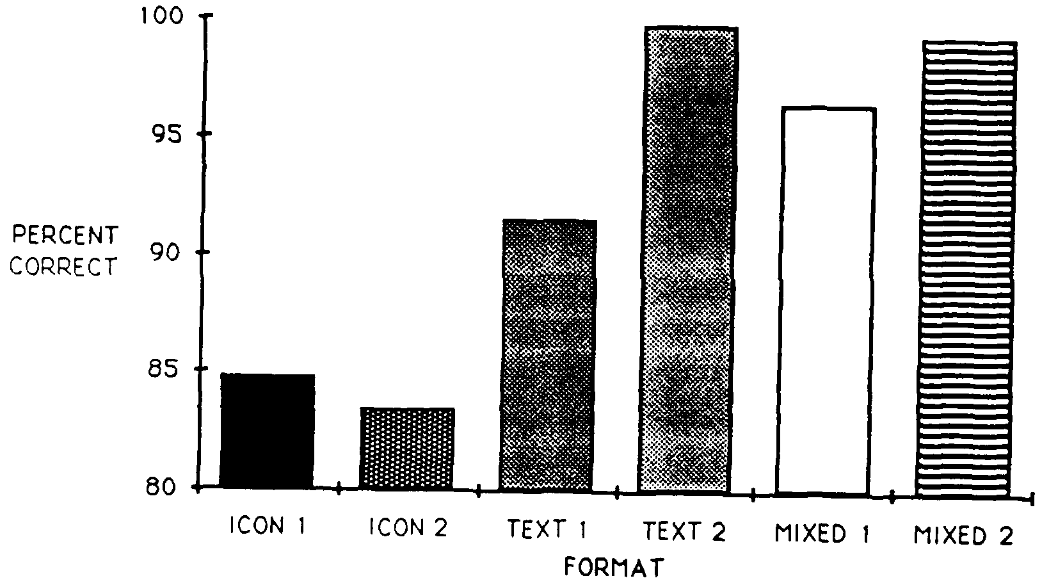


FIGURE 25. AVERAGE COMBINED RECALL PERCENT CORRECT RESPONSES - FORMAT BY SETBLOCK

command/function representations. Additionally, a confusion matrix delimits confusions between word processing functions. It is possible that confusion between representations exists because the concept itself is not well understood. Therefore, it would be difficult to successfully exploit differentiating characteristics of the function either textually, and/or graphically.

As indicated in the methods section, subject responses were recorded when responses did not match the designation of the stimuli. Tables 32 - 43 indicate the raw error data as a function of task (primary, and secondary recall), format (icon, text, and mixed) and response error category (internal, external). An example of the internal response error classification would be responding "Beginning of block" to the "Beginning of line" stimulus. While "Beginning of block" is a legitimate response, it is so only when applied to the "Beginning of block" representation. An external error is defined as a response which is not a member of the function or response set. For example, "Eliminate a line", is not a word processing function as defined by the acquisition task designations (a further classification of response errors was attempted, and is detailed in the discussion section).

Tables 44 and 45 provide a summary of the response errors detailed in Tables 32 - 43. The tables detail error data by task (primary and secondary), and are arranged alphabetically by functions. Additionally, they delineate the number of response errors by format and setblock.

Table 46 is provided as a summary of response errors as a function of task (primary, secondary and combined), format (icon, text, and mixed) and setblock (basic, enhanced).

The confusion matrices do not support any specific analyses per se, but they do provide a convenient method for assessing and evaluating the type and frequency of response errors. As indicated above, confusion matrices are particularly useful in identifying the functions, and/or representations that are the most frequently confused.

TABLE 32. Confusion Matrix: Icons - Primary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block		3/7	1/3																	4/10
Begin. of Line	/3		1/						/1										/1	1/5
Begin. of Text	3/1	1/										3/								7/1
Delete Line																				
Delete Paragraph																				
Delete Word													/1							/1
Double Space			1/														1/		1/5	3/5
End of Block									4/3	/2								1/1		5/6
End of Line		1/													/1			/1		1/2
End of Text								3/6	2/2		/1						/1			5/10
Footer	2/							1/								1/				4/
Header			/1																	/1
Insert Word						/1														/1
Justify										1/								/1		1/1
Left Justify																				
Page Break									/1	/1	10/9						1/1			11/12
Paginate								2/		2/	1/1									5/1
Right Justify								/1							/1					/2
Single Space				3/			2/2				1/						/1			6/3
Totals	5/4	5/7	3/4	3/		/1	2/2	6/7	6/6	3/3	12/11	3/	/1		/2	1/	2/3	1/3	1/6	53/61

Number of basic set errors → 4/6 ← Number of enhanced set errors

TABLE 33. Confusion Matrix: Icons - Primary Recall External Response Set Errors

	Add a Word	Begin. of Paragraph	Begin. of Page	Begin. of Sentence	Blackout Line	Blind Start	Delete Block	Delete Line	Delete Sentence	Delete Text	End of Page	End of Paragraph	Insert Line	Insert Paragraph	New Page	Page Continues	Remove Block	Start Block	Totals
Begin. of Block		3/1				/1							/1					1/	4/3
Begin. of Line		/1						1/											1/1
Begin. of Text			1/1																1/1
Delete Line				1/	/1				2/1										3/2
Delete Paragraph							1/3							1/			1/		3/3
Delete Word																			
Double Space										1/									1/
End of Block												4/3							4/3
End of Line													2/1						2/1
End of Text											3/2	/1							3/3
Footer																			
Header																			
Insert Word	/1																		/1
Justify																			
Left Justify																			
Page Break											2/				1/	1/			4/
Paginate												/1							/1
Right Justify																			
Single Space																			
Totals	/1	3/2	1/1	1/	/1	/1	1/3	1/	2/1	1/	5/2	4/5	2/2	1/	1/	1/	1/	1/	26/19

Number of basic set errors → 4/6 ← Number of enhanced set errors

TABLE 34. Confusion Matrix: Text - Primary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block																1				1
Begin. of Line								1												1
Begin. of Text								2												2
Delete Line																				
Delete Paragraph							2													2
Delete Word																				
Double Space																				
End of Block																				
End of Line																				
End of Text																				
Footer																				
Header																				
Insert Word																				
Justify																		1		1
Left Justify																				
Page Break																				
Paginate																2				2
Right Justify																				
Single Space									1											1
Totals							2	3	1							3		1		10

Number of basic set errors → 4/6 ← Number of enhanced set errors

TABLE 35. Confusion Matrix: Text - Primary Recall External Response Set Errors

	Begin Body	Begin. of Page	Begin. of Paragraph	Black-out Block	Block	Block Line	Delete Page	Delete Sentence	Delete Space	Designated Word	Eliminate Line	End Break	End of Page	Enter Line	Enter Text	Erase Line	Finish	Index Word	Page	Page Block	Paragraph	Paragraph Begins	Paragrsph Block	Short Space	Totals
Begin. of Block	1	1		1																					3
Begin. of Line					1	2																			3
Begin. of Text																									
Delete Line									1																1
Delete Paragraph							3																		3
Delete Word										1															1
Double Space								10		1															11
End of Block												1	1												2
End of Line														1											1
End of Text															1										1
Footer																	1								1
Header								1																	1
Insert Word											1							1							2
Justify																1									1
Left Justify																									
Page Break																				2		1	1		4
Paginate			1																3/1		4				8/1
Right Justify																									
Single Space																								1	1
Totals	1	1	1	1	1	2	3	11	1	2	1	1	1	1	1	1	1	1	3/1	2	4	1	1	1	43/1

Number of basic set errors

4/6

Number of enhanced set errors

TABLE 36. Confusion Matrix: Mixed - Primary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block		1/																		1/
Begin. of Line	1/1																			1/1
Begin. of Text	2/																			2/
Delete Line																				
Delete Paragraph																				
Delete Word																				
Double Space																				
End of Block																				
End of Line																			/1	/1
End of Text																				
Footer																				
Header																				
Insert Word																				
Justify																		1/		1/
Left Justify																				
Page Break																				
Paginate																				
Right Justify																				
Single Space																				
Totals	3/1	1/																1/	/1	5/2

Number of basic set errors

4/6

Number of enhanced set errors

TABLE 37. Confusion Matrix: Mixed - Primary Recall External Response Set Errors

	Begin. of Paragraph	Delete Sentence	Edge Break	End of Page	End of Paragraph	Enter Line	Enter Text	Page	Page Block	Start Line	Totals
Begin. of Block											
Begin. of Line										/1	/1
Begin. of Text											
Delete Line		1									1
Delete Paragraph											
Delete Word											
Double Space		2									2
End of Block			1								1
End of Line						1					1
End of Text							1				1
Footer											
Header											
Insert Word											
Justify											
Left Justify											
Page Break								1	2		3
Paginate	1			/1	1			1			3/1
Right Justify											
Single Space											
Totals	1	3	1	/1	1	1	1	2	2	/1	12/2

Number of basic set errors → 4/6 ← Number of enhanced set errors

TABLE 38. Confusion Matrix: Icons - Secondary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block		/3	8/5						1/											
Begin. of Line	/2		1/1						1/					/2					/1	
Begin. of Text	3/2	1/1										3/1								
Delete Line																			/1	
Delete Paragraph																				
Delete Word													4/1							
Double Space			2/			1/								/3			/1		/3	
End of Block									5/3	/2										
End of Line								1/1												
End of Text								2/4	1/											
Footer			1/					/1								3/	1/			
Header	/1														1/					
Insert Word				/1		2/														
Justify										1/							1/			
Left Justify														1/						
Page Break								1/		/1	10/9						1/1			
Paginate										1/1	1/1									
Right Justify															1/					
Single Space							/3				2/			/4			1/2			
Totals																				

Number of basic set errors

4/6

Number of enhanced set errors

TABLE 39. Confusion Matrix: Icon - Primary Recall External Response Set Errors

	Begin.& End of Text	Begin.of Line	Begin.of Page	Begin.of Paragraph	Begin.of Sentence	Bottom of Page	Continue Page	Delete Block	Eliminate Line	End of Page	End of Paragraph	End of Sentence	Heading	Insert	Insert Line	Insert Paragraph	Insert Space	Justification	Left Margin	Omit Word	Page Number	Paragraph	Right Margin	Top of Page	Totals
Begin. of Block				1/1															/1						
Begin. of Line					1/2																				
Begin. of Text		/1	3/2										/1												
Delete Line															/1		1/								
Delete Paragraph								4/4								4/						1/			
Delete Word																				/1					
Double Space																		/1							
End of Block																									
End of Line												/1											/1		
End of Text										3/1	2/4														
Footer																									
Header									/1															1/	
Insert Word														/1											
Justify	/1																								
Left Justify																									
Page Break						/1	/1																		
Paginate																					1/				
Right Justify																									
Single Space																									
Totals																									

Legend: $\boxed{4/6}$ — Number of basic set errors (4); Number of enhanced set errors (6)

TABLE 40. Confusion Matrix: Text - Secondary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block		1/																		1/
Begin. of Line																				
Begin. of Text																				
Delete Line							1/													1/
Delete Paragraph							1/													1/
Delete Word																				
Double Space																				
End of Block																				
End of Line																				
End of Text																				
Footer																				
Header																				
Insert Word																				
Justify								1/	1/				1/		1/					4/
Left Justify																				
Page Break																				
Paginate																				
Right Justify																				
Single Space																				
Totals		1/					2/	1/	1/				1/		1/					7/

Number of basic set errors → 4/6 ← Number of enhanced set errors

TABLE 41. Confusion Matrix: Text - Primary Recall External Response Set Errors

	Begin. of Box	Begin Paragraph	Begin. of Paragraph	Block	Block Left	Delete Page	Delete Page Output	Delete Sentence	Delete Space	Double Play	Edit	Edit Box	End of Break	End of Page	Enter Text	Indent Word	Insert Paragraph	Page	Page Block	Paragraph	Paragraph Block	Paragraph Break	Paragraph Indent	Previous Page	Short Stop	Start of Sentence	Totals
Begin. of Block	1/																					1/					
Begin. of Line				2/	1/																						
Begin. of Text																											
Delete Line																											
Delete Paragraph						1/	1/			1/																	
Delete Word																											
Double Space								6/	2/																		
End of Block												1/	1/														
End of Line																											
End of Text											1/				1/												
Footer																											
Header																											
Insert Word																1/		/1									
Justify																											
Left Justify																											
Page Break			2/															1/	1/		1/			1/			
Paginate		1/	1/											1/			1/			3/			/1				
Right Justify																				1/							
Single Space																									1/	1/	
Totals																											

Number of basic set errors

4/6

Number of enhanced set errors

TABLE 42. Confusion Matrix: Mixed - Secondary Recall Response Set Errors

	Begin. of Block	Begin. of Line	Begin. of Text	Delete Line	Delete Paragraph	Delete Word	Double Space	End of Block	End of Line	End of Text	Footer	Header	Insert Word	Justify	Left Justify	Page Break	Paginate	Right Justify	Single Space	Totals
Begin. of Block																				
Begin. of Line	1/																			
Begin. of Text																				
Delete Line																				
Delete Paragraph																				
Delete Word																				
Double Space																				
End of Block									/1											/1
End of Line																				
End of Text																				
Footer																1/				1/
Header																				
Insert Word																				
Justify																		1/		1/
Left Justify																				
Page Break											1/						2/			3/
Paginate																				
Right Justify																				
Single Space																				
Totals	1/								/1		1/					1/	2/	1/		6/1

Number of basic set errors → 4/6 ← Number of enhanced set errors

Table 43. Confusion Matrix: Mixed - Primary Recall External Response Set Errors

	Begin. of Box	Begin. of Break	Begin. of Page	Begin. of Paragraph	Block	Delete Sentence	Eliminate Line	End of Box	End of Break	End of Page	End of Paragraph	Finish Page	Page Blank	Page Block	Page Bottom	Paragraph	Right & left Justify	Totals
Begin. of Block	1/	1/	1/															
Begin. of Line					1/													
Begin. of Text																		
Delete Line						1/												
Delete Paragraph																		
Delete Word																		
Double Space						2/												
End of Block								1/	1/		1/							
End of Line							1/											
End of Text													1/					
Footer												1/						
Header																		
Insert Word																		
Justify																	/1	
Left Justify																		
Page Break										/1			1/	1/				
Paginate				/1											/1			
Right Justify																		
Single Space																		
Totals																		

Number of basic set errors

4/6

Number of enhanced set errors

Table 44. Primary Recall Response Errors

Function	Icon Set 1	Icon Set 2	Total	Text Set 1	Text Set 2	Total	Mixed Set 1	Mixed Set 2	Total
Begin. of Block	8	12	20	4		4	1		1
Begin. of Line	2	7	9	4		4	1	2	3
Begin. of Text	8	2	10	2		2	2		2
Delete Line	3	2	5	1		1	1		1
Delete Paragraph	3	3	6	5		5			
Delete Word		1	1	1		1			
Double Space	4	5	9	10		10	2		2
End of Block	9	9	18	2		2	1		1
End of Line	3	3	6	1		1	1	1	2
End of Text	8	13	21	1		1	1		1
Footer	4		4	1		1			
Header		1	1	1		1			
Insert Word		2	2	2		2			
Justify	1	1	2	2		2	1		1
Left Justify									
Page Break	14	10	24	4		4	3		3
Paginate	5	2	7	10	1	11	3	1	4
Right Justify		22		2		2			
Single Space	6	3	9						
Total Errors	78	79	156	53	1	54	17	4	21

Table 45. Secondary Recall Response Errors

Function	Icon Set 1	Icon Set 2	Total	Text Set 1	Text Set 2	Total	Mixed Set 1	Mixed Set 2	Total
Begin. of Block	10	11	21	3		3	3		3
Begin. of Line	3	8	11	3		3	2		2
Begin. of Text	10	9	19						
Delete Line	1	2	3	1		1	1		1
Delete Paragraph	9	4	13	4		4			
Delete Word	4	2	6						
Double Space	3	8	11	8		8	2		2
End of Block	8	12	20	2		2	3	1	4
End of Line	1	4	5				1		1
End of Text	8	9	17	2		2	1		1
Footer	5	1	6				2		2
Header	2	2	4						
Insert Word	2	2	4	1	1	2			
Justify	2	1	3	4		4	1	1	2
Left Justify	1		1						
Page Break	14	14	28	6		6	5	1	6
Paginate	5	4	9	7	1	8	2		2
Right Justify	2	1	3	1		1			
Single Space	3	9	12	2		2			
Total Errors	93	103	196	44	2	46	23	3	26

Table 46. Summary Table of Response Errors

Format	Set 1 Response Errors	Set 2 Response Errors	Total
Primary Recall			
Icon	78	80	138
Text	53	1	54
Mixed	17	4	21
Totals	148	85	213
Secondary Recall			
Icon	93	103	196
Text	44	2	46
Mixed	23	3	26
Totals	160	108	268
Combined			
Icon	171	183	354
Text	97	3	100
Mixed	40	7	47
Totals	308	193	501

Similarly, they are useful in formulating hypotheses that summarize the characteristics of response errors.

Preference

Subject preference data was utilized to determine the correlation between preference and: average acquisition time, average primary recall response time, average primary recall response errors, average secondary recall response time, and average recall response errors.

Individual preference data was transformed into measures indicative of two sets of representations for each of the three presentation formats. As the objective was to correlate preference for presentation formats (i.e., icon, text, mixed) as opposed to preference for a particular presentation (e.g., justify), each of the format sets was ranked according to it's cumulative ranks sums. This was achieved by summing the rank score for each of the format sets, for each word processing function, for each subject.

To amplify, all subjects evaluated all 19 word processing functions. Each word processing function was represented in six separate ways, two "equivalent" representations (basic, enhanced) for each presentation format (icon, text and mixed). The preference rating for the iconic representation of justify for basic was added to the preference rank for the iconic representation for paginate function (also basic). This was iterated for each subject for all word processing functions, until six rank sum values were computed. The relative ranking for each presentation format was then determined and entered into the appropriate table. Similarly, the same approach was utilized for average response times and response errors. Specifically, the response times and errors for each of the tasks (acquisition, primary and secondary recall), for each subject was summarized into a single arithmetic average. This average was then ranked relative to the remaining categories.

The difference between the preference ranking and secondary ranking (acquisition time) was computed. The difference score was squared and finally reduced into a summary statistic. This transformed difference parameter serves as the basis for the correlation coefficient.

The Spearman rho correlation procedure was used because of its general acceptance, ease of application, and the availability of significance test procedure.

The significance test was simply the comparison between the achieved correlation and a tabled value corresponding to a specific alpha level and sample size. The exact null hypothesis tested was that the population correlation is equal to zero (no correlation). As indicated by Tables 47 - 51, for an alpha level of .05 and the number of ranks equal to six (6), the obtained value would have to exceed .886 (Linton & Gallo, 1975).

A significant correlation would be interpreted as meaning the two measures (preference and any of the dependent measures) correspond. With respect to response time measures, shorter response times would be evaluated as either the most, or least preferred. Similarly, with respect to error measures, a significant correlation would be indicative of a high degree of agreement between preference rating and number of response errors. Correlation coefficients can be positive or negative, indicating the actual relationship between variables. A positive correlation indicates that both variables coincide, while a negative correlation is indicative of just the reverse (e.g., a high preference rating and slow response time).

As indicated by Tables 47 - 51, on the average, the most preferred Format was the text - enhanced Format. The next most preferred format was the mixed - enhanced format. It was preferred, in turn to the text - basic, which was followed in decreasing order of preference by the icon - enhanced and the mixed - basic formats. The least preferred representation was the icon - basic format.

Table 47. Spearman Rho Correlation Coefficient and Significance Test: Preference and Acquisition Time.

Format	Preference Rank	Acquisition Rank	d	d^2
Icon - basic	6	2	4.	16.
Icon - enhanced	4	1	3.	9.
Text - basic	3	3	0.	0.
Text - enhanced	1	4	-3.	9.
Mixed - basic	5	6	-1.	1.
Mixed - enhanced	2	5	-3.	9.
Total			0.	44.

Correlation Coefficient:

$$1 - \frac{6(44)}{6(62 - 1)} = -.2571$$

Significance Test:

alpha	.05
sample size	30
tabled value	.886
observed value	-.2571

$|-.2571| < .886$

Table 48. Spearman Rho Correlation Coefficient and Significance Test: Preference and Primary Recall Response Time.

Format	Preference Rank	Acquisition Rank	d	d^2
Icon - basic	6	6	0.	0.
Icon - enhanced	4	5	-1.	1.
Text - basic	3	3	0.	0.
Text - enhanced	1	1	0.	0.
Mixed - basic	5	4	1.	1.
Mixed - enhanced	2	2	0.	0.
Total			0.	2.

Correlation Coefficient:

$$1 - \frac{6(2)}{6(6^2 - 1)} = .9428$$

Significance Test:

alpha	.05
sample size	30
tabled value	.886
observed value	.9428

.9428 > .886

Table 49. Spearman Rho Correlation Coefficient and Significance Test: Preference and Primary Recall Response Errors.

Format	Preference Rank	Acquisition Rank	d	d^2
Icon - basic	6	5	1.	1.
Icon - enhanced	4	6	-2.	4.
Text - basic	3	4	-1.	1.
Text - enhanced	1	1	0.	0.
Mixed - basic	5	3	2.	4.
Mixed - enhanced	2	2	0.	0.
Total			0.	10.

Correlation Coefficient:

$$1 - \frac{6(10)}{6(62 - 1)} = .7143$$

Significance Test:

alpha	.05
sample size	30
tabled value	.886
observed value	.7143

.7143 < .886

Table 50. Spearman Rho Correlation Coefficient and Significance Test: Preference and Secondary Recall Response Time.

Format	Preference Rank	Acquisition Rank	d	d^2
Icon - basic	6	2	4.	16.
Icon - enhanced	4	1	3.	9.
Text - basic	3	4	-1.	1.
Text - enhanced	1	3	-2.	4.
Mixed - basic	5	6	-1.	1.
Mixed - enhanced	2	5	-3.	9.
Total			0.	40.

Correlation Coefficient:

$$1 - \frac{6(40)}{6(62 - 1)} = -.1428$$

Significance Test:

alpha	.05
sample size	30
tabled value	.886
observed value	-.1428

$|-.1428| < .886$

Table 51. Spearman Rho Correlation Coefficient and Significance Test: Preference and Secondary Recall Response Errors.

Format	Preference Rank	Acquisition Rank	d	d^2
Icon - basic	6	5	1.	1.
Icon - enhanced	4	6	-2.	4.
Text - basic	3	4	-1.	1.
Text - enhanced	1	1	0.	0.
Mixed - basic	5	3	2.	4.
Mixed - enhanced	2	2	0.	0.
Total			0.	10.

Correlation Coefficient:

$$1 - \frac{6(40)}{6(6^2 - 1)} = .7143$$

Significance Test:

alpha	.05
sample size	30
tabled value	.886
observed value	.7143

.7143 < .886

As reported in Table 52 a significant correlation was obtained between preference and primary recall response time (correlation coefficient of .9428). Indicating, that for those measures, on the average, subject performance and preference directly coincided (a positive relationship between average preference rating and average primary recall response time was achieved). That is, with respect to the primary recall task, average preference rating is a reasonably good predictor or indicator of performance (recall response time). While significance was not achieved, an apparent trend is that subjects tended to prefer stimuli belonging to the enhanced group.

The other correlation coefficients did not achieve the strength required to be considered significant (they did achieve moderate correlations). However, one result deserving of special note is the correlation between preference and acquisition time. The correlation achieved a slightly inverse relationship, indicating that preference is a particularly bad indicator of how long it takes for the average individual to learn a particular stimuli set (preference has little association with time required to learn)

Table 52. Summary Table of Significant Effects

		Primary Recall Task		Secondary Recall Task		Combined	
Effect	Acquisition Time	Time	Percent Correct	Time	Percent Correct	Time	Percent Correct
Experience(Exp)							
Format (Ft)	.01	.01	.01	.01	.01	.01	.01
Exp * Ft							
Setblock (Set)		.01	.01	.01	.01	.01	.01
Exp * Set			.05		.05		.01
Session (S)							
Exp * Sess							
Ft * Set		.01	.01	.01	.01	.01	.01
Exp * Ft * Set							
Ft * Sess							
Exp * Ft * Sess							
Set * Sess							
Exp * Set * Sess							
Ft * Set * Sess						.05	
Exp * Ft * Set * Sess							

Correlation .9428

Discussion and Conclusion

Discussion

Experience

Experience was expected to significantly influence acquisition, primary and secondary recall response times, as well as the number of primary and secondary recall response errors. As shown in the summary of main effects listed in Table 52, there are no significant effects for experience. However, three two-way interactions and one three-way interaction did achieve significance. Specifically, the primary and secondary recall experience by setblock two-way interactions utilizing percent correct responses as dependent measures achieved significance ($p < .05$). The combined two-way experience by setblock interaction utilizing percent correct responses achieved significance ($p < .01$).

Referring to Tables 15, 22, and 30, the analyses indicate that the significant differences in response errors were primarily between the low experience subjects when compared to the medium and high experience subjects (few significant differences were obtained between the medium and high experience groups).

As it was operationally defined, experience appears to be a qualitative as opposed to a quantitative factor. Subjects able to claim word processing experience, regardless of the form (word processor/word processing program), were able to correctly identify significantly more stimuli than novices. If a person has gained some experience in word processing, additional experience does not appear to enhance that person's ability to correctly identify word processing representations. A more rigorous operationalization of the variable, experience, may lead to different results.

Format

The primary motivation for this research was to study the effect of presentation format on acquisition time, recall, and preference. The main focus was on the relative difference between iconic and textual representations. As indicated in Table 52 the main effect of presentation format (icon, text and mixed) was significant in all analyses ($p < .01$).

Review of Table 9, reveals a significant difference in the average learning time between the text and icon formats, and between the text and mixed formats. In both instances the text format was learned significantly faster, indicating that subjects were more adept at interpreting and assimilating textual representations of word processing functions than either the icon or mixed formats. This result is contrasted with the findings of the remainder of the Newman-Keuls analyses (Tables 11, 14, 18, 21, 25 and 29), which indicate significant differences between the icon and text formats, and the icon and mixed formats, but no significant differences between the text and mixed formats. These findings indicate that on average, subjects require longer to recall iconic representations than either the text or mixed formats, and that subjects make errors more frequently when evaluating icon representations as compared with text or mixed representations. As detailed below, it is believed that these results are due to the design and implementation of the experimental tasks.

Setblock

The setblock variable was introduced as a mechanism to provide more generalizable results, and to establish the utility of evaluating rules sets via the resulting stimuli. Accordingly, it was hypothesized that average response time and response errors would be directly effected by the rules used to develop the experimental stimuli. As noted in Table 52, with the exception of acquisition time, the significant main effect of setblock supports this hypothesis. Additionally, results of the Newman-Keuls analyses of the significant format by setblock interactions support the contention that rule sets developed for specific formats demonstrate the same significant effect.

Specific findings indicate that the enhanced set (text and mixed) required significantly less time to provide a response, and that enhanced stimuli were correctly identified significantly more frequently. These findings are thought to be attributable to the production rules that were applied in developing the stimuli. The fewer enhanced response errors are thought to be attributed to the more complete text representations of the textual and mixed stimuli. The explanation is supported by the error data as detailed in Table 46. The icon response error data is approximately the same in both basic and enhanced conditions.

In regard to the icon - enhanced response time (and graphic portion of the mixed) stimuli, the benefits of a graphic command were enhanced by a secondary coding scheme. It was hypothesized that the secondary code would reduce the search time required to detect the meaningful aspect of each stimuli and thus the overall response time. However, this hypothesis was not supported.

As indicated by the average response time and average response error figures provided in the results section, the setblock conditions (basic, enhanced) represent discontinuous data and therefore are presented as histograms or bar charts rather than line graphs. An underlying issue with evaluating rule sets is the ability to systematically vary (and compare) rule sets along some common and meaningful dimension(s). This ability would be necessary in order to quantify the effect on a dependent measure as a consequence of a specific rule change or variance. Given the number of potential rules and their possible variations, it is not a trivial issue.

Session

The original hypotheses about session effects were developed in the belief that retention would be differentially affected by one or more of the presentation formats (or second-order interactions). The session effect would be reflected as significantly longer recall times and larger numbers of response errors (lower percent correct responses) as a function of format and setblocks. However, as evidenced by Table 52, the only significant ($p < .05$) session effect achieved was the three-way format by setblock by session interaction using response time as a dependent measure. Table 27 indicates that all significant response time differences were achieved between the primary and secondary recall text, and mixed - enhanced, and the mixed - basic conditions compared with all remaining combinations. In fact, the ordering of the response times within Table 27 indicates that with respect to those three conditions (text - enhanced, mixed - basic, and mixed - enhanced), the average primary recall response time was followed immediately by the corresponding condition in the secondary recall task. Once again, indicating the superiority of the text - enhanced, mixed - basic, and - enhanced conditions.

Conclusion

It must be emphasized that in all tasks, subjects were instructed to learn and/or recall the provided designation, as opposed to the meaning of a representation. Therefore, as indicated in the results section, a response was evaluated as incorrect, if the designation and response did not match exactly. For example, responding "start of block" to the "beginning of block" command was scored as an error. Semantically, "beginning of block" and "start of block" are similar. In all likelihood, the findings with respect to response time and errors would differ had subjects been requested to provide a meaning rather than a specific term for each representation. This conclusion is supported in part, by the finding that with the exception of acquisition time, dependent measures did not significantly differ between the text and mixed formats. Since the common element between the mixed and text formats was the textual portion, and the text format most closely approximated the designation, it is likely that the most significant aspect of stimuli is the textual portion. This conclusion is further supported by the Newman-Keuls analyses of significant format by setblock interactions (Tables 12, 16, 19, 23, 26, and 31) where the average response times for the text - enhanced, and mixed - enhanced conditions were significantly shorter than for any other combination. Again the distinguishing aspect would appear to be the text of the stimuli. Specifically, the text of enhanced setblock stimuli, more closely resembled the correct designation than it did in the basic stimuli. This result is essentially replicated when comparing the percent correct responses data. That is, the enhanced text and mixed representations were correctly identified more frequently than any of the other format and setblock combination.

The most robust support of this conclusion comes from an examination of the significant differences in setblock error data. The error rate for icons is approximately constant between sets for both primary and secondary recall tasks, while the relative error rate of enhanced stimuli for both the text and mixed representations drop off sharply (Table 46). The difference between the sets, is the extent to which the textual portion of the stimuli reflects the correct designation. Had the number of icon enhanced response errors dropped off, some other mechanism would be required to explain the effect, since the icon sets do not possess any text characters.

If the response error evaluation criteria were relaxed, and the meaning of responses were taken into account, the difference in number of errors between formats would diminish. It is possible that a relaxation of the semantic evaluation criteria would benefit the icon format more than any other group.

An assessment of response error data presented in the confusion matrices, as well as subjects' comments, indicates that response could be classified into one of the following (3) three general categories: over-generalization, confusion, and domain errors.

Over-generalization

An examination of response errors indicates that subjects had some understanding of the rules that were applied to develop the commands but applied them inappropriately to formulate a response. For example, responding "page block" to "PB" (text basic) stimuli, indicates some knowledge of the abbreviation rules used to develop the command. Specifically, the first character corresponds to the first letter of the first part of the command, and the second character corresponds to the first letter of the second portion of the designation. This particular error also demonstrates some notion of the domain errors described below.

Confusion

The response indicates either a poor understanding of the critical aspects of the representation and its referent or an inability to differentiate the subtle defining aspects of the representation. For example, responding "beginning of block" to the iconic representation of "beginning of line", is indicative of failure to recognize the significant differentiating aspect of the two functions (and/or corresponding representation). This specific error could also be classified as a domain error.

Domain errors

Domain errors are response errors made due to a deficiency in an understanding of the subject matter. For example, responding "delete block" to the "delete paragraph" icon stimuli, may indicate a failure to distinguish between paragraph and block. In the broadest sense, these errors represent syntactical errors.

It should be stressed that any error could be classified into several categories, and that the error categories are not mutually exclusive but rather reflect interpretation of the response given, the stimuli condition.

Examination of the three error categories indicates that the frequency distribution of the error types is a function of the format (Table 46).

Summary

In an attempt to summarize the results and findings of the study, the following recommendations/observations are set forth:

- With the exception of novices, word processing experience does not dramatically influence the time required to learn or recall stimuli. Similarly, experience does not affect the number of response errors made.
- Word processing systems which require subjects to learn and recall exact command sets benefit from enhanced text or enhanced text with graphics.
- In applications where a precise verbal response is required, or where differences between functions is subtle, use of an accepted term in conjunction with a graphic is the preferred method.
- In general, preference appears to be a poor predictor of performance. Therefore, preference should not be the only basis for deciding on command set formats. However, when subject preference is the primary driver, enhanced text commands should be used. The next preferred approach is the mixed enhanced command set.

In regard to the Army,the results of the pilot study indicate that the format used to represent a command affects the learning and recall characteristics of the command. Specifically, the number of recall errors as well as the time required to learn and recall commands are affected by the command format. Of more direct significance, the results suggest that the Army could improve the effectiveness of the soldier-computer interface of current systems by employing at a minimum, an abbreviation scheme similar to that used to derive the enhanced text set. For existing or proposed systems that can support a graphic interface, a combination of the enhanced text rule set and the enhanced iconic rule set would result in the most efficient interface.

While these findings were demonstrated using word processing commands as a domain, they may prove to hold in other areas more germane to "*providing the soldier the decisive edge.*". It is expected that development of systems using command sets analogous to the enhanced command sets of the present study will enhance the overall effectiveness of the system. This hypothesis will be tested in the follow on effort.

The second phase of the effort will focus on developing a command and control interface concept appropriate to the needs and interests of the U. S. Army in general, and of specific interests to USAHEL. As yet, this system remains undefined. However, command representations will be modeled after rule sets similar to the ones utilized in the present study. Additionally, the concept of transactional metaphors presented in the literature review will be explored for applicability to the second phase effort.

Recommendations for further research

As indicated above, different results would be expected if subjects were requested to learn and recall the meaning of a specific representation (semantics), as opposed to a specific term or designation (syntax). The primary rationale for this conclusion rests on the strong relationship that exists between the text format condition and the designation as defined in the present study. Future research should include an analysis of the semantic relationship between a representation and its function.

Additionally, if semantic meaning, as opposed to a specific term, is evaluated, the responses would indicate which designations in the present stimuli set relate directly to the function (as compared to the designation), and correspondingly make good representations of word processing functions.

Finally, the point that the relationship between the task and the textual representation is stronger than the relationship between the graphic depiction and the designation could be supported or refuted.

Generalization

Analysis of other domains with the same methodology should be encouraged to determine if these results are specific to word processing representations, or if they can be generalized to other applications. As indicated above, the follow on effort will focus on the development of an interface concept for a specific command and control application. Subsequent efforts will be directed at expanding the number and type of generalizations.

Development and validation of a meaningful error taxonomy capable of differentiating between response errors as a function of production rules would further improve the user computer interface development environment.

Finally, a more precise operational definition of experience may result in a more precise understanding of interactions between experience and dependent variables.

References

Allen, R.W., Parseghian, Z., and Van Valkenburgh. (1980). A simulator of age effects on symbol sign recognition. In Proceedings of the Human Factors Society - 24th Annual Meeting, (pp. 471-475). Santa Monica, CA: Human Factors Society.

Anderson, J.R. (1980). Cognitive psychology and its implications. San Francisco: W. H. Freeman and Company.

Arblaster, A. (1982). Human factors in the design and use of computer languages. International Journal of Man-Machine Studies, 17 (2), 211-224.

Bass, L.J. (1985). An approach to user specification of interactive display interfaces. Software, SE-11 (8), 686-698.

Barnard, P., Hammond, N., MacLean, A., and Morton, J. (1982). Learning and remembering interactive commands. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 2-7).

Bedno, E. (1972). A program for developing visual symbols. Visible Language, 6, 355-363.

Berzins, V. (1985). Analysis and design in MSG. 84: Formalizing functional specifications. Software, SE-11, 657-670.

Bewley, W.L., Roberts, T.L., Schroit, D. and Verplank, W.L. (1983). Human factors testing in the design of Xerox's 8010 'Star' office workstation. (1983). In CHI '83 Human Factors in Computing Systems (pp. 72-77). New York: Association for Computing Machinery.

Black, J.B., and Moran, T.P. (1982). Learning and remembering command names. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 8-11).

Booher, H.R. (1975). Relative comprehensibility of pictorial information and printed words in proceduralized instructions. Human Factors, 17, 226-277.

Brainard, R.W., Campbell, R.J. and Elkin, E.H. (1961). Design and interpretability of road signs. Journal of Applied Psychology, 45, 130-136.

Brown, G.P., Carling, R.T., Herot, C.F., Kramlich, D.A., and Souza, P. (1985). Program visualization: Graphical support for software development. Computer, 18 (8), 27-34.

Brown, M.H. and Sedgewick, R. (1984). A system for algorithm animation. Computer Graphics, 18 (3), 177-186.

Bruning, J.L., and Kintz, B.L. (1968). Computational Handbook of Statistics. Scott, Foresman and Company, Atlanta.

Cahill, M.C. (1975). Interpretability of graphics symbols as a function of context and experience factors. Journal of Applied Psychology, 60, 376-380.

Cairney, P.T., and Sless, D. (1982). Communication effectiveness of symbolic safety signs with different user groups. Applied Ergonomics, 13, 91-97.

Caron, J.P., Jamieson, D.G., and Dewar, R.E. (1980). Evaluating pictographs using semantic differential and classification techniques. Ergonomics, 23 (2),137-146.

Carter, R.J. (1979). Standardization of geometric radar symbology: Stereotyped meanings and paper-and-pencil testing. In Proceedings of the Human Factors Society, 23rd Annual Meeting, (pp. 443-447). Santa Monica, CA: Human Factors Society.

Chi, U.H. (1985). Formal specification of user interfaces: A comparison and evaluation of four axiomatic approaches. Software, SE-11 (8), 671-685.

Clark, B.E.J., and Robinson, S.K. (1983). A graphically interactive program monitor. Computer Journal, 26 (3), 235-238.

Coleman, M.L. (1969). Text editing on a graphics display device using hand drawn proofreading symbols. In Proceedings of the 2nd University of Illinois Conference on Computer Graphics.

Collins, B.L. (1983). Evaluation of mine-safety symbols. In Proceedings of the Human Factors Society, 27th Annual Meeting, (pp. 947-949). Santa Monica, CA: Human Factors Society.

Collins, B.L., and Lerner, N.D. (1982). Assessment of fire-safety symbols Human Factors, 24 (1), 75-84.

Collins, B.L., and Pierman, B.C. (1979). Evaluation of safety symbols (Tech. Report NBSIR 79-1760). Gaithersburg, MD: National Bureau of Standards.

Coutaz, J. (1985). Abstractions for user interface design. Computer, 18 (9), 21-34.

Davis, E.G., and Sweezy, R.W. (1983). Human factors guidelines in computer graphics: A case study. International Journal of Man-Machine Studies, 18 (2), 113-133.

Dewar, R.E., and Ells, J.G. (1974). Comparison of three methods for evaluating traffic signs. Transportation Research Record, 503, 38-47.

Dewar, R.E., and Ells, J.G. (1976). Factors influencing the perception of traffic signs. (1976). Toronto: University of Calgary, Psychology Department.

Dewar, R.E., and Ells, J.G. (1976). The semantic differential as an index of traffic sign perception and comprehension. Human Factors, 18,381-392.

Dewar, R.E., Ells, J.G., and Mundy, G. (1976). Reaction time as an index of traffic sign perception. Human Factors, 18, 381-392.

Dewar, R.E., and Swanson, H.A.(1972). Recognition of traffic control signs. Highway Research Board Proceedings, 414, 16-23.

Douglas, S., and Moran, T.P. (1983). Learning text editing by analogy. In CHI '83 Human Factors in Computing Systems (pp. 207-211). New York: Association for Computing Machinery.

Dreyfus, H. (1966). Case study: Symbols for industrial use. In G. Kepes (Ed.), Sign, Image, Symbol (pp.126-133). New York: Braziller.

Dreyfus, H. (1972). Symbol Source Book. New York, McGraw-Hill.

Easterby, R.S. (1967). Perceptual organization in static displays for man/machine systems. Ergonomics. 10, 195-205.

Easterby, R.S. (1972). The perception of symbols for machine displays. Ergonomics. 13, (1) 149-158.

Easterby, R.S., and Hakiel, S.R. (1977a). Safety labeling and consumer products: Field studies of sign recognition. (AP Report 76). University of Aston in Birmingham, England: Applied Psychology Department.

Easterby, R.S., and Zwaga, H.G. (1977b). Evaluation of public information symbols, ISO tests: 1975 series. (AP Report 76). University of Aston in Birmingham, England: Applied Psychology Department.

Egan, D.E., Bowers, C., and Gomez, L.M. (1982). Learner characteristics that predict success in using a text editor tutorial. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 337-340).

Ells, J.G., and Dewar, R.E. (1979). Rapid comprehension of verbal and symbolic traffic sign messages. Human Factors, 21,161-168.

Embley, D.W., and Nagy, G. (1981). Behavioral aspects of text editors. Computing Surveys, 13,(1), 33-70.

Federal Highway Administration, Department of Transportation.(1984). Manual on uniform traffic control devices for streets and highways. Washington, DC.

Finseth, C.A. (1982). Managing words: What capabilities should you have with a text editor ? Byte, 7 (4), 302-310.

Finzer, W., and Gould, L. (1984). Programming by rehearsal. Byte, 9 (6), 187-210.

Fitter, M.J. (1979). Towards more natural interactive systems. International Journal of Man-Machine Studies, 11 (3), 339-350.

Folley, L., and Williges, R. C. (1982). User models of text editing command languages. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 326-331).

Foss, D.J., Rosson, M.B., and Smith, P. (1982). Reducing manual labor: An experimental analysis of learning aids for a text editor. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 332-336).

Frank, L.K.(1966). The world as a communication network. In G. Kepes (Ed.), Sign, Image, Symbol (pp.126-133). New York: Braziller.

Getz, S.L., Kalligiannis, G., and Schach, S.R. (1983). A very high-level interactive trace for the Pascal heap. IEEE Transactions on Software Engineering, SE-9 (2), 179-185.

Gomez, L.M., Egan, D.E., Wheeler, E.A., Sharma, D.K., and Gruchacz, A.M. (1983). How interface design determines who has difficulty learning to use a text editor. In Proceedings CHI'83 Human Factors in Computing Systems, (pp. 166-170). New York: Association for Computing Machinery.

Glinert, E.P.(1985). PICT: Experiments in the design of interactive, graphical programming environments. Unpublished doctoral dissertation, University of Washington, Seattle, WA.

Glinert, E.P., and Tanimoto, S.L. (1984). Pict: An interactive graphical programming environment. Computer, 17 (11), 7-25.

Green, P. (1977). The prediction of choice response times for pictographic symbols. (Technical Report). The University of Michigan, Ann Arbor: Department of Industrial Operations and Engineering.

Green, P.(1979). Development of pictographic symbols for vehicle controls and displays. (Technical Report 790383). New York: Society of Automotive Engineers.

Green, P., and Davis, G. (1976). The recognition time of related pictograhic symbols for automotive controls. Journal of Safety Research, 8 (4), 180-183.

Green, P., and Pew, R.W. (1978). Evaluating pictographic symbols: An automotive application. Human Factors, 20, 103-114.

Grether, W.F., and Baker, C.A. (1963). Visual presentation of information. In H.P. Van Cott and R.G. Kinkade (Eds.) Human Engineering Guide to Equipment Design (pp.41-121),(revised edition). Washington, D.C.: Government Printing Office.

Griffith, D., and Actkinson, T.R. (1978). International road signs: Interpretability and training techniques. (Technical Report 1202). U.S. Army Research Institute for the Behavioral and Social Sciences, Alexandria, VA.

Haber, R.N., and Erdelyi, M.H. (1967). Emergence and recovery of initially unavailable perceptual material. Journal of Verbal Learning and Verbal Behavior, 6, 618-628.

Hartson, H.R., and Johnson, D.H. (1983). Dialogue management: New concepts in human-computer interface development. Virginia Polytechnic Institute and State University, Blacksburg, VA: Computer Science & Industrial Engineering Operations Research.

Hays, W.L. (1963). Statistics for Psychologists. Holt, Rinehart and Winston, New York.

Hawkins, J.S., Reising, J.M., Lizza, G.D., and Beachy, K.A. (1983). Is a picture worth 1000 words-- Written or spoken? In Proceedings of the Human Factors Society, 27th Annual Meeting, (pp. 970-972). Santa Monica, CA: Human Factors Society.

Hawkins, J.S., Reising, J.M., Woodson, B.K., and Bertling, S.J. (1984). A study of programmable switch symbology. In Proceedings of the Human Factors Society 28th Annual Meeting (pp.118-122). Santa Monica, CA: Human Factors Society.

Heard, E.A. (1974). Symbol study - 1972. (Technical Report 740304). New York: Society of Automotive Engineers.

Hemenway, K. (1982). Psychological issues in the use of icons in command menus. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 20-25).

Howell, W.C., and Fuchs, A.H. (1968). Population stereotypy in code design. Organizational Behavior and Human Performance, 3, 310-339.

Innocent, P.R. (1982). Towards self adaptive interface systems International Journal of Man-Machine Studies, 16 (3), 287-299.

Jack, D. (1972). Identification of controls: A study of symbols. (Technical Report 720203). New York: Society of Automotive Engineers.

Jacob, R.J.K. (1983). Using formal specifications in the design of a human-computer interface. Communications of the ACM, 26 (4), 259-264.

Jacob, R.J.K. (1985). A state transition diagram language for visual programming. Computer, 18 (8), 51-59.

Jones, S. (1983). Sterotypy in pictograms of abstract concepts. Ergonomics, 26, (6), 605-611.

King, L.E. (1971). A laboratory comparison of symbol and Ward roadway signs. Traffic Engineering and Control, 12, 518-520.

Kirk, R.E.(1968). Experimental design: Procedures for the behavioral sciences. Belmont, CA: Wadsworth.

Kolb, J.(1967). Symbols in machine control speak in all languages. Product Engineering, 38, 100-107.

Kolers, P.A. (1969). Some formal characteristics of pictograms. American Scientist, 57, 348-363.

Kraut, R.E., Hanson, S.J., and Farber, J.M.(1983). Command use and interface design.In CHI '83 Human Factors in Computing Systems (pp. 120-124). New York: Association for Computing Machinery.

Lakin, F.H. (1980). A structure from manipulation for text-graphic objects. ACM Computer Graphics, 14 (3), 100-107.

Lee, A., and Lochovsky, F.H. (1983). Enhancing the usability of an office information system through direct manipulation. In CHI '83 Human Factors in Computing Systems (pp. 130-134). New York: Association for Computing Machinery.

Lerner, N.D., and Collins, B.L. (1983). Symbol sign understandability when visability is poor. In Proceedings of the Human Factors Society, 27th Annual Meeting, (pp. 944-946). Santa Monica, CA: Human Factors Society.

Lewis, J.W. (1983). An effective graphics user interface for rules and inference mechanisms. In CHI '83 Human Factors in Computing Systems (pp. 139-143). New York: Association for Computing Machinery.

Lindquist, T.E. (1984). Assessing the usability of human - computer interfaces. Software, 2 (1), 74-82.

Lindquist, T.E., Fainter, R.G., Hakkinen, M.T., Guy, S.R., and Maynard, J.F. (1983). GENIE: A computer-based task for experiments in human computer interaction. Virginia Polytechnic Institute & State University, Blacksburg, VA: Computer Science & Industrial Engineering Operations Research.

Linton, M., and Gallo, P.S. (1975). The practical statistician: Simplified handbook of statistics. Monterey, California: Brooks/Cole.

Lodding, K.N. (1983). Iconic interfacing. Computer Graphics and Applications. 3 (2), 11-20.

Mack, R.L., Lewis, C.H., and Carroll, J.M. (1983). Learning to use word processors: Problems and prospects. ACM transactions on Office Information Systems, 1 (3), 254-271.

Mackett-Stout, J. and Dewar, R. (1981). Evaluation of symbolic public information signs. Human Factors, 23 (2), 139-151.

Mayer, R.E. (1981). The psychology of how novices learn computer programming. Computing Surveys, 13 (1), 121-141.

Melamed, B., and Morris, R.J.T. (1985). Visual simulation: The performance analysis workstation. Computer, 18 (8), 87-94.

MicroPro (1982). WordStar quick reference guide. San Rafael, CA: MicroPro International Corporation.

Modley, R., and Myers, W.R. (1976). Handbook of pictorial symbols. New York: Dover Publications.

Moran, T.P. (1983). Getting into a system: External-internal task mapping analysis. In CHI '83 Human Factors in Computing Systems (pp. 45-49). New York: Association for Computing Machinery.

Moses, F.L., Maisano, R.E., and Bersh, P. (1979). "Natural" associations between symbols and military information. In Proceedings of the Human Factors Society, 23rd Annual Meeting, (pp.438-442). Santa Monica CA: Human Factors Society.

Muter, P., and Johns, E.E. (1985). Learning logographies and alphabetic codes. Human Learning, 4, 1-21.

Norman, D.A. (1983). Design principles for human-computer interfaces. In CHI '83 Human Factors in Computing Systems (pp.1-10). New York: Association for Computing Machinery.

Norman, D.A. (1983). Design rules based on analyses of human error. Communications of the ACM, 26 (4), 254-258.

Nugent, G.C. (1982). Pictures, audio, and print: Symbolic representation and effect on learning. Educational Communication and Technology Journal, 30, 163-174.

Poller, M.F., and Garter, S.K. (1983). A comparative study of moded and modeless text editing by experienced editor users. In Proceedings CHI'83 Human Factors in Computing Systems, (pp. 166-170). New York: Association for Computing Machinery.

Purcell, W.F. (1967). Symbols: A common Language. Automotive Industries, 136, 67-70

Roach, J.W., and Nickson, M. (1983). Formal specifications for modeling and developing human-computer interfaces. In CHI '83 Human Factors in Computing Systems (pp. 35-40). New York: Association for Computing Machinery.

Roberts, T.L. and Moran, T.P. (1983). The evaluation of text editors: Methodology and empirical results. Communications of the ACM, 26, 265-283.

Rogers, Y. (1986). Pictorial representations of abstract concepts relating to human-computer interaction. Unpublished session notes CHI'86, Boston.

Rogers, Y., and Oborne, D.J. (1985). Some psychological attributes of potential computer command names. Behavior and Information Technology. 4, (4), 349-365.

Rohr, G., and Keppel, E. (1984). Iconic interfaces: Where to use and how to construct? In Proceedings of First Symposium on Human Factors in Organizational Design and Management. (pp 269-275).

Root, R.W., and Draper, S. (1983). Questionnaires as a software evaluation tool. In CHI '83 Human Factors in Computing Systems (pp. 83-87). New York: Association for Computing Machinery.

Rosenberg, J. (1982). Evaluating the suggestiveness of command names. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 12-16).

Rosenberg, J. (1983). A featural approach to command names. In Proceedings CHI'83 Human Factors in Computing Systems, (pp. 116-119). New York: Association for Computing Machinery.

Rosson, M.B. (1983). Patterns of experience in text editing. In Proceedings CHI'83 Human Factors in Computing Systems, (pp. 171-175). New York: Association for Computing Machinery.

Rothstein, P.R.(1985). Designing warnings to be read and remembered. In Proceedings of the Human Factors Society, 29th Annual Meeting, (pp. 684-688). Santa Monica, CA: Human Factors Society.

Ryan, T.A., and Schwartz, C.B.(1956). Speed of perception as a function of mode of representation. American Journal of Psychology, 69, 193-199.

Scapin, D.L. (1982). Computer commands labeled by users versus imposed commands and the effect of structuring rules on recall. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 17-23).

Shu, N.C. (1985). Formal: A forms-oriented, visual directed application development system. Computer, 18 (8), 38-49.

Sloan, G.D. (1983). Handedness may be more important than sex as a variable underlying individual differences in visual performance. In Proceedings of the Human Factors Society, 27th Annual Meeting, (pp. 715-719). Santa Monica, CA: Human Factors Society.

Sloan, G.D., and Eshelman, P. (1981). The development and evaluation of pictographic symbols. In Proceedings of the Human Factors Society, 25th Annual Meeting, (pp. 198-202). Santa Monica, CA: Human Factors Society.

Smith, D.C. (1975). Pygmalion: A creative programming environment. Unpublished doctoral dissertation, Stanford University, Menlo Park, CA.

Smith, D.C., Irby, C., Kimball, R., Verplank, B., and Harslem, E. (1982). Designing the STAR user interface. Byte, 7 (4), 242-282.

Smith, G., and Weir, R. (1978). Laboratory visibility studies of directional symbols used for traffic control signals. Ergonomics, 21 (4), 247-252.

Somberg, B.L. and Dotson, K.E., (1985). Methods of disambiguating command term abbreviations for interactive computer systems. In Proceedings of the Human Factors Society, 29th Annual Meeting, (pp. 659-663). Santa Monica, CA: Human Factors Society.

Stern, K.R. (1984). An evaluation of written, graphics, and voice messages in proceduralized instructions. In Proceedings of the Human Factors Society 28th Annual Meeting (pp. 314-318). Santa Monica, CA: Human Factors Society.

Tandy Corporation (1979). SCRIPSIT word processing system training program. Fort Worth: Tandy Corporation.

Tyler, S.W., Roth, S., and Post, T. (1982). The acquisition of text editing skills. In Proceedings on Human Factors in Computer Systems. Gaithersburg, MD. (pp 324-325).

Ursic, M. (1984). Research Note: The impact of safety warnings on perception and memory. Human Factors, 26 (6), 677-682.

Van Cott , H.P., and Kinkade, R.G. (Eds.). (1972). Human Engineering Guide to Equipment Design., (revised edition), Washington, D.C.: Government Printing Office.

Walker, R.W., Nicolay, R.C., and Stearns, C.R. (1965). Comparative accuracy of recognizing American and international road symbols. Journal of Applied Psychology, 49, 322-325.

Williams, G. (1983). The Lisa computer system. Byte, 8, (2), 33-50.

Zwaga, H.J. and Z, T. (1983). Evaluation of a set of graphics symbols. Applied Ergonomics, 14, 43-54.

APPENDIX A
Participant Eligibility
Questionnaire Form

Participant Eligibility Questionnaire Form

NAME: ____________________________________
Please print

PHONE: ____________________________
Local

AGE: ________

SEX:

__ Male

__ Female

EXPERIENCE:

1) Approximate experience with typewriters: __________ months.

2) **a** Approximate number of word **processors** you have practical first hand experience with __________ (if the answer is zero, skip to question # 3, otherwise continue with question # 2b).

b In the space provided, list the word **processor** system(s) you have had prior experience with. Additionally, adjacent to each system entry, please complete the other entries related to use of each word processing **system** (if additional space is required, please note the entries on the reverse side of this page).

	Word Processing System	Experience (months)	Usage Frequency (per week)	Usage Duration (min.)
1)				
2)				
3)				
4)				
5)				

3) **a** Approximate number of word processing **programs** you have practical first hand experience with __________ (if the answer is zero, skip to question # 4, otherwise continue with question # 3b).

b In the space provided, list the word processing **program(s)** you have had prior experience with (if additional space is required, please note the entries on the reverse side of this page).

Word Processing **Program**	Experience (months)	**Usage** Frequency (per week)	Duration (min.)
1) ______________________	______	______	______
2) ______________________	______	______	______
3) ______________________	______	______	______
4) ______________________	______	______	______
5) ______________________	______	______	______

4) Of the options provided below, select the descriptor that you feel best describes or characterizes your word processing usage/knowledge.

__ Low
__ Medium
__ High

Thank you for your time and cooperation.

Please return the completed form to the experimenter. If any further participation is required on your part the experimenter will contact you directly.

APPENDIX B
Participant Consent
Form

PARTICIPANT CONSENT FORM

To contact experimenter, call:
698-6225 (O) 8:30-5:30 weekdays
239-0414 (H) after normal work hours

As a participant in this experiment, you have several rights. The objective of this form is to explicitly identify and explain those rights. Please carefully read the form, prior to signing it at the bottom. If there is any point about which you are confused or unclear please ask the experimenter.

Confidentiality

As a participant, your rights to confidentiality are to be protected. To verify that this right will not be violated, several steps to protect your identity have been devised and will be employed. The first is of these measures is to explain the data collection procedure. To provide a method of accurate data collection, data will be collected and stored by a computer. This approach implies that a "permanent record" of transactions will be made. Upon successful completion of this experiment, all computer files will be destroyed.

Withdrawal

As a participant, you maintain a right to withdraw from the experiment at any time for any reason. Additionally, you have the right to request that your data be removed from any or all analyses. In order to effect this, the experimenter must be informed of your intent immediately after completion of a session (for as soon as is reasonable). You will be paid for your participation in accordance with the agreement below (regardless of whether or you elect to grant permission to use your data).

Knowledge of results

As a participant, you are entitled to results of your data in particular and/or results in general. All interested individuals will be provided with a summary of results, findings and recommendations as derived from the study. Interested individuals must provided me with a mailing address where the summary can be forwarded (if you are a student, please provide "permanent" address) in the appropriate location on this form. It will take approximately three months to compile and analyze the data.

Payment

For your participation, you will be paid at the rate of $10.00 per hour (or portion thereof). Payment will be upon completion of the last session or upon termination of your participation. In either case, you will be paid by check, and must signify receipt of payment at that time. As the master schedule will be the primary basis for payment, you are requested to be flexible (and at the same time reasonable) with respect to arrangement of sessions. You will not be paid for time in which you are not present at scheduled sessions. However, if there are times when you must wait for the experimenter, you will be paid the agreed upon rate. If there are changes in your schedule or emergency conflicts please let the experimenter know as soon as possible. Unusual circumstances will be considered on a case by case basis with final rulings made by an impartial third party.

It is my sincerest hope that participation in this study will prove both interesting and stimulating. To the extent possible (without biassing results), I will be glad to respond to any questions in regard to procedure, participation etc.

Your signature below indicates that you have both read and understand your rights as a participant and that you agree to participate accordingly. If you include your permanent address in the space provided, when available, You will be provided a copy of a summary of experimental results.

Signature:______________________________

Date:____/____/____ ________-______-__________
Social Security Number

Printed Name:______________________________

Address: ______________________________
Street

____
County State Zip

Please detach this sheet from the rest and give it to the experimenter. If you need to get hold of the experimenter for any reason you can contact him directly at the telephone number(s) provided on the cover sheet (or leave a message).

APPENDIX C

Subject Instructions

To minimize the possibility of experimenter biassing effects on subjects, and to standardize instructions across individuals and sessions, subjects were instructed via a set of charts. The content, format and organization of the instruction set is provided in the following section.

The instruction set was pretested (by individuals representative of the subject population), was considered to be self-explanatory. However, the organization of the instructions may not be obvious when considered out of context. Specifically, the instructions correspond to the proposed acquisition, primary and secondary recall tasks.

Your participation in this study will require that you complete five tasks. The first four tasks require the use of this computer. Therefore, it is necessary for you to understand how to use it, and to feel comfortable with its features.

To control the computer, place the cursor over any area of the screen designated as a 'button', and depress the mouse button once (locate the cursor by moving the mouse). Now, place the cursor over the 'Next button' and depress the mouse button.

'NEXT BUTTON' ->

NEXT

For the remainder of this experiment, every time the computer requires an input, you will be prompted with a labeled 'button'. As appropriate, place the cursor over the button and depress the mouse button.

NEXT

In the next several screens, you will be presented objects that should be familiar to you.
In addition to a graphic portion, each screen will include a title or designation.

For each screen or slide, you are to:

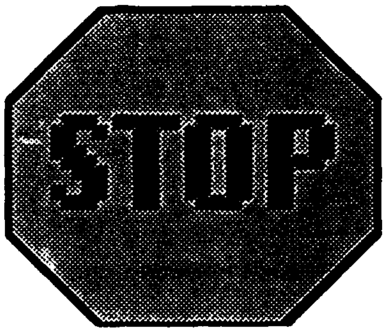
- read the designation aloud
- view each slide as long as you feel is necessary, such that you could reliably provide the proper designation if requested to do so.

NEXT

After viewing these slides you will be provided further instructions.
If you have any questions or, you are not sure what is expected of you, take this opportunity to request assistance from the experimenter.

NEXT

This completes the first set of tasks. Please do NOT proceed to the next slide until directed to do so by the experimenter.



NEXT

The next set of slides involves several representations of the word processing functions you read aloud previously.

As before, you are requested to do two things.

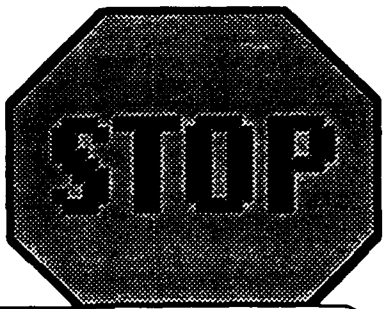
- read the designation aloud.
- view each slide as long as necessary, such that you could provide the proper designation if requested to do so.

NEXT

After viewing these slides you will be provided further instructions.
If you have any questions or, you are not sure what is expected of you, take this opportunity to request assistance from the experimenter.

NEXT

This completes the second task.
Please do NOT proceed to the next slide until directed to do so by the experimenter.



NEXT

The instructions for this segment of the experiment are very similar to the instructions to the previous section with one major exception You may note, that the title or designation associated with each slide has been ommitted.

Rather than reading the designation of each slide (as before), you are to provide the experimenter with the appropriate designation (verbally). Respond as quickly, but as carefully as you can. At the same time you respond, depress the 'I got it button'.

NEXT

After viewing these slides you will be provided further instructions.
If you have any questions or, you are not sure what is expected of you, take this opportunity to request assistance from the experimenter.

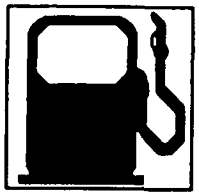
NEXT

This completes this session.....
Thank you for your participation.

I Got It!!

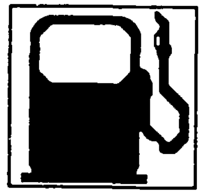
APPENDIX D
Practice Set

PRIMARY RECALL
PRACTICE



FUEL

SECONDARY RECALL
PRACTICE

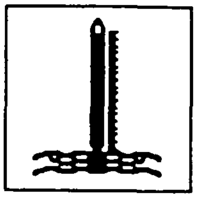


PRIMARY RECALL
PRACTICE

BAR

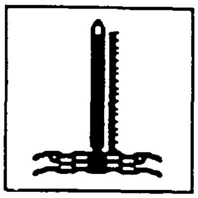
SECONDARY RECALL
PRACTICE

PRIMARY RECALL
PRACTICE

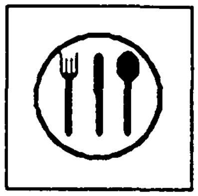


WATER TEMPERATURE

SECONDARY RECALL
PRACTICE

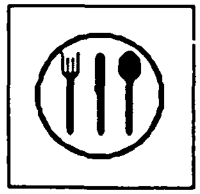


PRIMARY RECALL
PRACTICE



FOOD

SECONDARY RECALL
PRACTICE

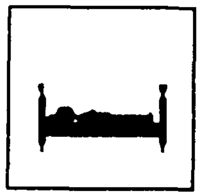


PRIMARY RECALL
PRACTICE

NO SMOKING

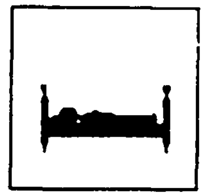
SECONDARY RECALL
PRACTICE

PRIMARY RECALL
PRACTICE



LODGING

SECONDARY RECALL
PRACTICE



APPENDIX E

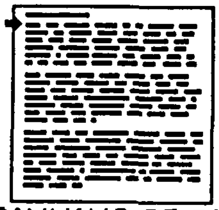
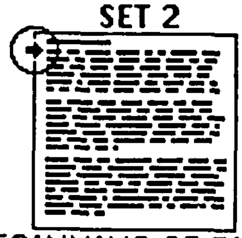
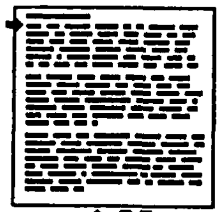
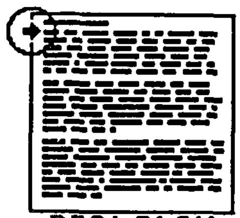
Stimuli Set

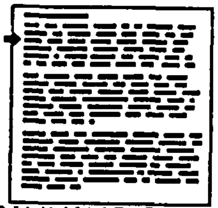
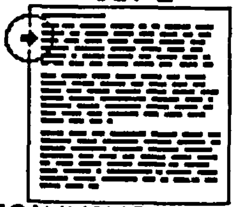
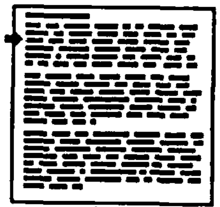
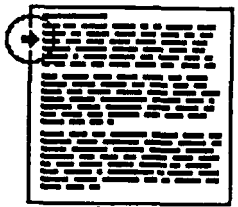
INDEX

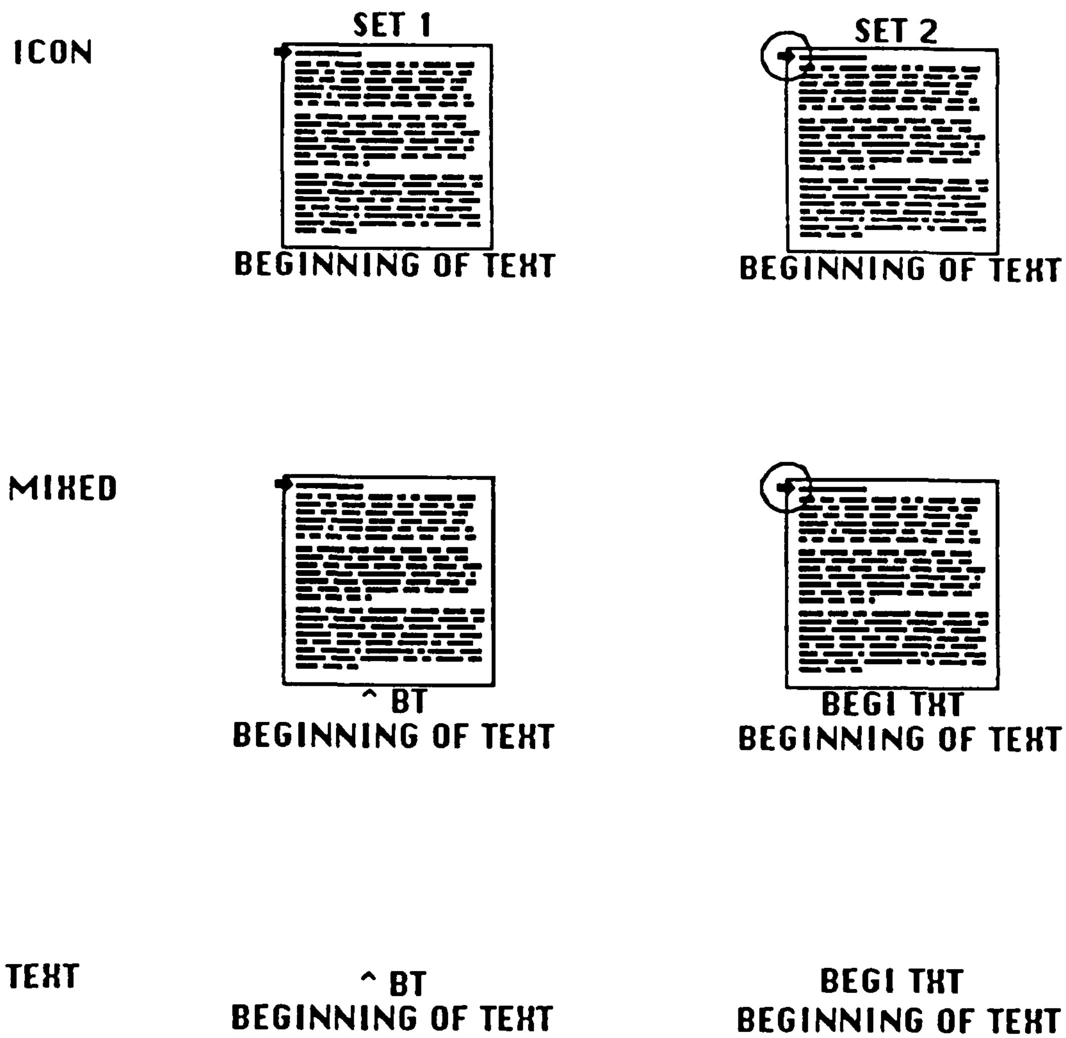
The accompanying slides or charts represent the complete set of stimuli used throughout the effort. The organization of the stimuli correspond to the acquisition, primary and secondary and recall tasks. Therefore, the complete set of acquisition slides is presented prior to the slides corresponding to the primary and secondary and recall tasks (identical sets).

For each set of stimuli (acquisition, primary and secondary and recall tasks), two equivalent representations for each format (icon, text and mixed) was developed. This resulted in the formation of six representations or stimuli per word processing function. To assist in reviewing the representations of particular word processing functions the following index (alphabetically arranged) was prepared.

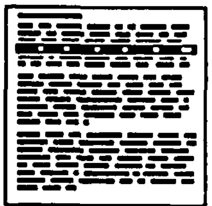
INDEX

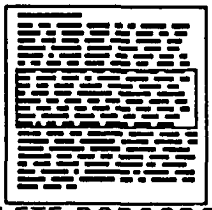
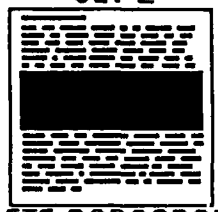
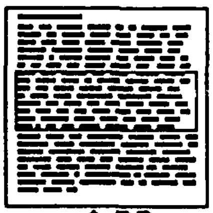
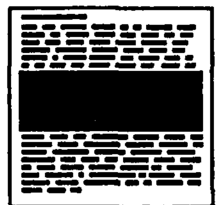
	SET 1	SET 2
ICON	 BEGINNING OF BLOCK	 BEGINNING OF BLOCK
MIXED	 ^ BB BEGINNING OF BLOCK	 BEGI BLCK BEGINNING OF BLOCK
TEXT	^ BB BEGINNING OF BLOCK	BEGI BLCK BEGINNING OF BLOCK

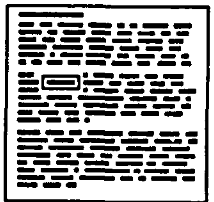
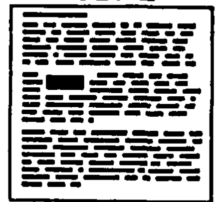
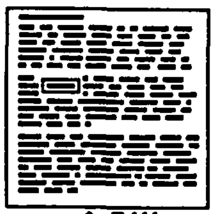
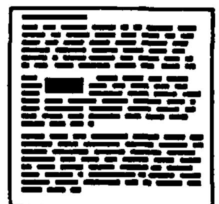
	SET 1	SET 2
ICON	 BEGINNING OF LINE	 BEGINNING OF LINE
MIXED	 ^ BL BEGINNING OF LINE	 BEGI LN BEGINNING OF LINE
TEXT	^ BL BEGINNING OF LINE	BEGI LN BEGINNING OF LINE

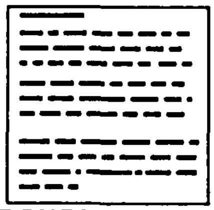
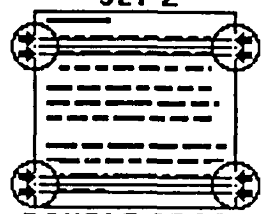
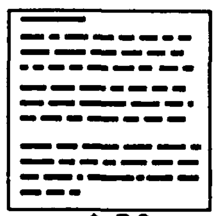
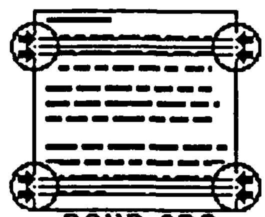


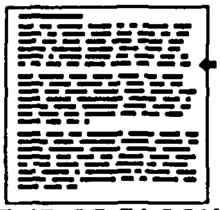
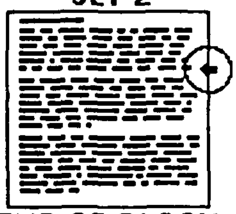
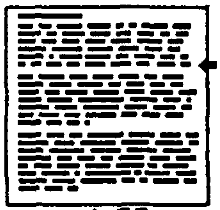
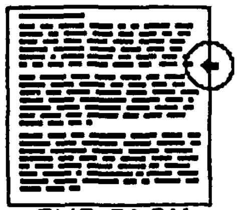
SET 1
SET 2
ICON
BEGINNING OF TEXT
BEGINNING OF TEXT
MIXED
^ BT
BEGINNING OF TEXT
BEGI TXT
BEGINNING OF TEXT
TEXT
^ BT
BEGINNING OF TEXT
BEGI TXT
BEGINNING OF TEXT

	SET 1	SET 2
ICON	 DELETE LINE	 DELETE LINE
MIXED	 ^ DL DELETE LINE	 DELE LN DELETE LINE
TEXT	^ DL DELETE LINE	DELE LN DELETE LINE

	SET 1	SET 2
ICON	 DELETE PARAGRAPH	 DELETE PARAGRAPH
MIXED	 ^ DP DELETE PARAGRAPH	 DELE PARA DELETE PARAGRAPH
TEXT	^ DP DELETE PARAGRAPH	DELE PARA DELETE PARAGRAPH

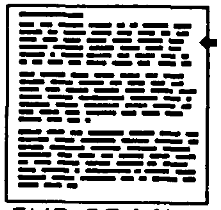
	SET 1	SET 2
ICON	 DELETE WORD	 DELETE WORD
MIXED	 ^ DW DELETE WORD	 DELE WRD DELETE WORD
TEXT	^ DW DELETE WORD	DELE WRD DELETE WORD

	SET 1	SET 2
ICON	 DOUBLE SPACE	 DOUBLE SPACE
MIXED	 ^ DS DOUBLE SPACE	 DOUB SPC DOUBLE SPACE
TEXT	^ DS DOUBLE SPACE	DOUB SPC DOUBLE SPACE

	SET 1	SET 2
ICON	 END OF BLOCK	 END OF BLOCK
MIXED	 ^ EB END OF BLOCK	 END BLCK END OF BLOCK
TEXT	^ EB END OF BLOCK	END BLCK END OF BLOCK

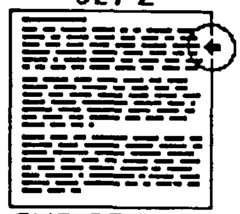
ICON

SET 1



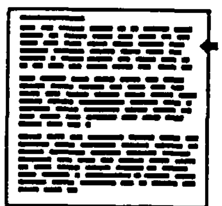
END OF LINE

SET 2

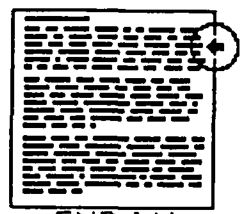


END OF LINE

MIXED



^ EL
END OF LINE

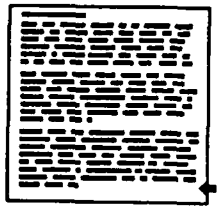
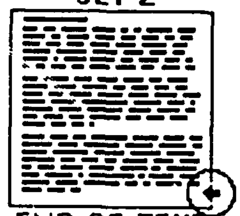
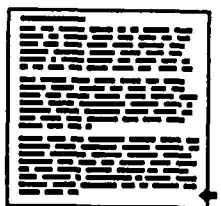
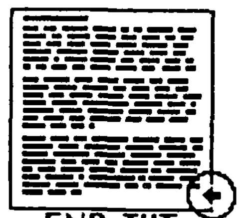


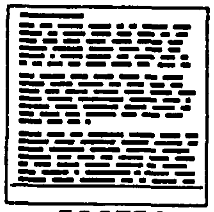
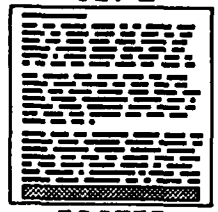
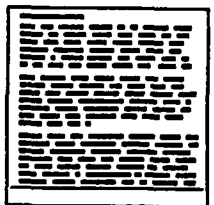
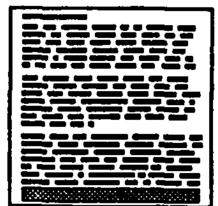
END LN
END OF LINE

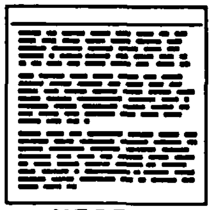
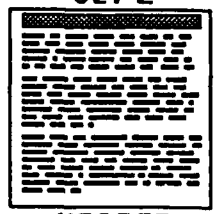
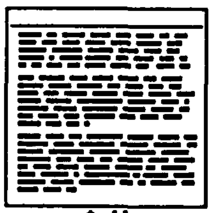
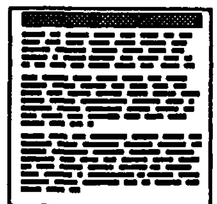
TEXT

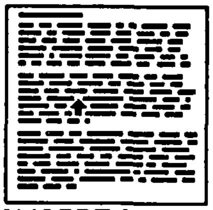
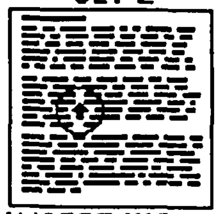
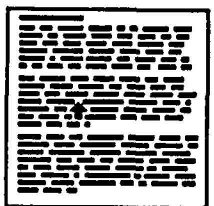
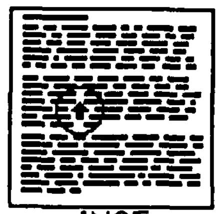
^ EL
END OF LINE

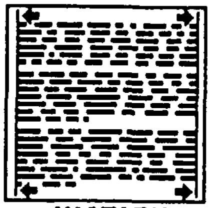
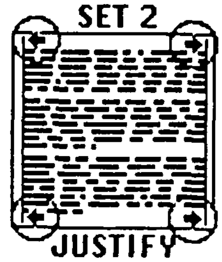
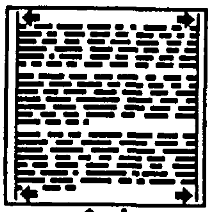
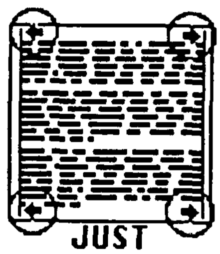
END LN
END OF LINE

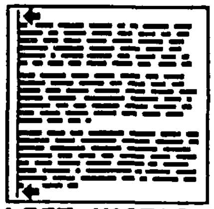
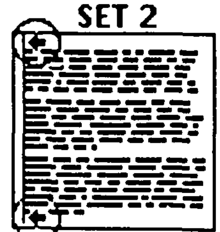
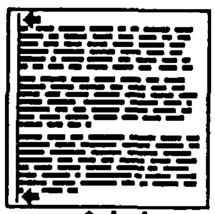
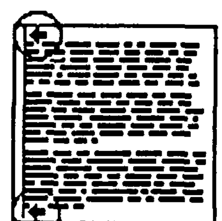
	SET 1	SET 2
ICON	 END OF TEXT	 END OF TEXT
MIXED	 ^ ET END OF TEXT	 END TXT END OF TEXT
TEXT	^ ET END OF TEXT	END TXT END OF TEXT

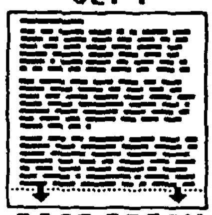
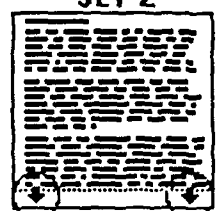
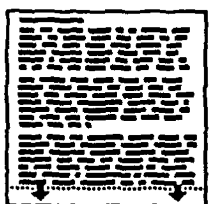
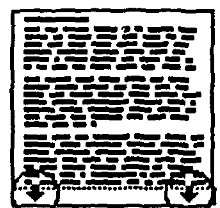
	SET 1	SET 2
ICON	 FOOTER	 FOOTER
MIXED	 ^ F FOOTER	 FOOT FOOTER
TEXT	^ F FOOTER	FOOT FOOTER

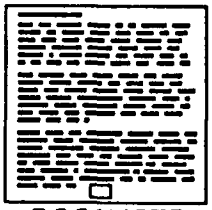
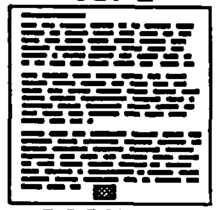
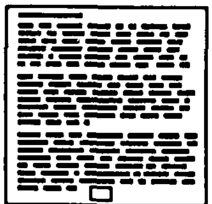
	SET 1	SET 2
ICON	 HEADER	 HEADER
MIXED	 ^ H HEADER	 HEAD HEADER
TEXT	^ H HEADER	HEAD HEADER

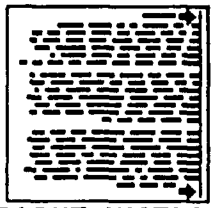
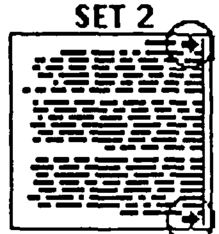
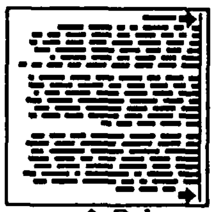
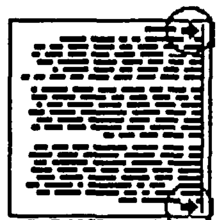
	SET 1	SET 2
ICON	 INSERT WORD	 INSERT WORD
MIXED	 ^ IW INSERT WORD	 INSE INSERT WORD
TEXT	^ IW INSERT WORD	INSE INSERT WORD

	SET 1	SET 2
ICON	 JUSTIFY	 JUSTIFY
MIXED	 ^ J JUSTIFY	 JUST JUSTIFY
TEXT	^ J JUSTIFY	JUST JUSTIFY

	SET 1	SET 2
ICON	 LEFT JUSTIFY	 LEFT JUSTIFY
MIXED	 ^ LJ LEFT JUSTIFY	 LEFT JUST LEFT JUSTIFY
TEXT	^ LJ LEFT JUSTIFY	LEFT JUST LEFT JUSTIFY

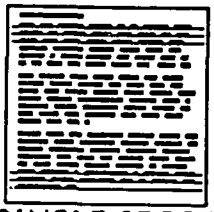
	SET 1	SET 2
ICON	 PAGE BREAK	 PAGE BREAK
MIXED	 ^ PB PAGE BREAK	 PAGE BRK PAGE BREAK
TEXT	^ PB PAGE BREAK	PAGE BRK PAGE BREAK

	SET 1	SET 2
ICON	 PAGINATE	 PAGINATE
MIXED	 ^ P PAGINATE	 PAGI PAGINATE
TEXT	^ P PAGINATE	PAGI PAGINATE

	SET 1	SET 2
ICON	 RIGHT JUSTIFY	 RIGHT JUSTIFY
MIXED	 ^ RJ RIGHT JUSTIFY	 RGHT JUST RIGHT JUSTIFY
TEXT	^ RJ RIGHT JUSTIFY	RGHT JUST RIGHT JUSTIFY

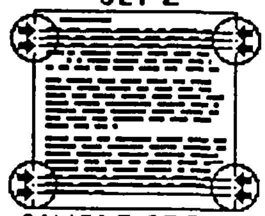
ICON

SET 1



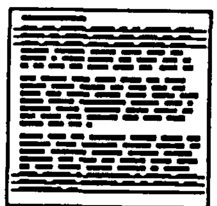
SINGLE SPACE

SET 2

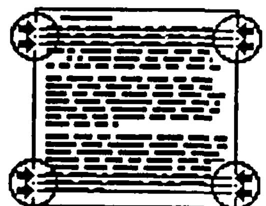


SINGLE SPACE

MIXED



^ SS
SINGLE SPACE

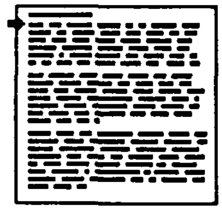
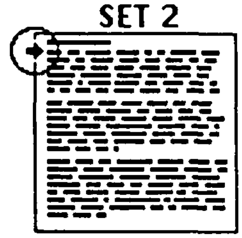
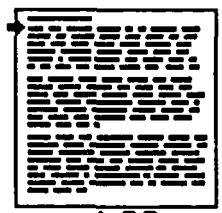
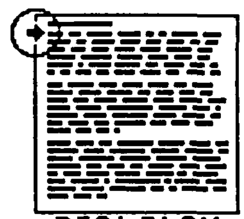


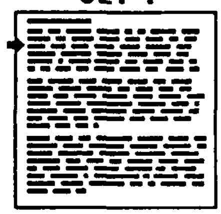
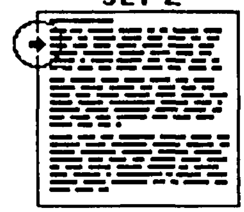
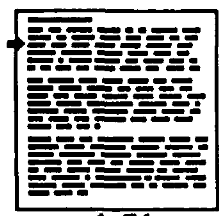
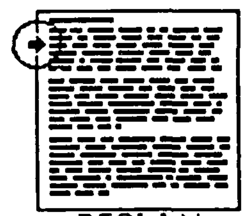
SING SPC
SINGLE SPACE

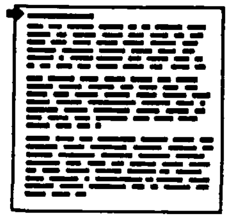
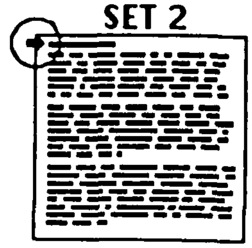
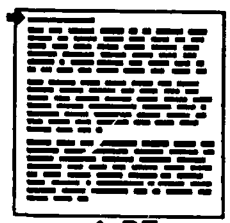
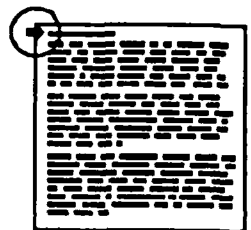
TEXT

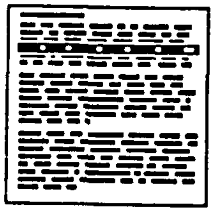
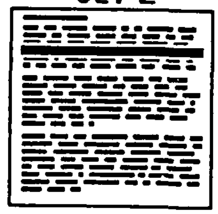
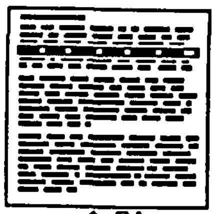
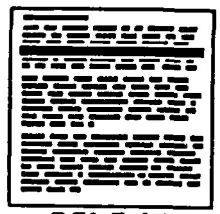
^ SS
SINGLE SPACE

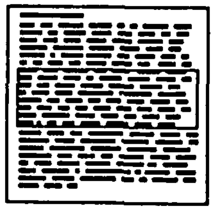
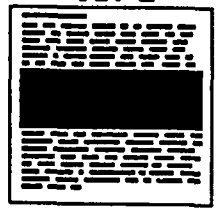
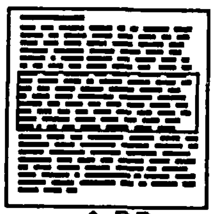
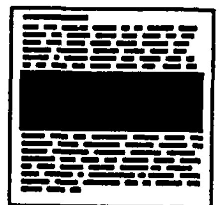
SING SPC
SINGLE SPACE

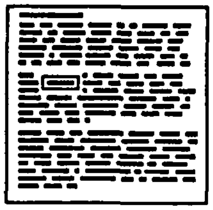
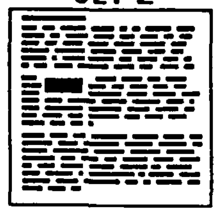
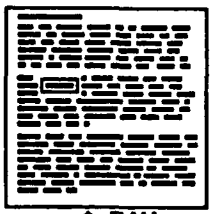
	SET 1	SET 2
ICON		
MIXED	 ^ BB	 BEGI BLCK
TEXT	^ BB	BEGI BLCK

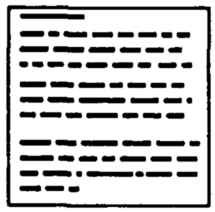
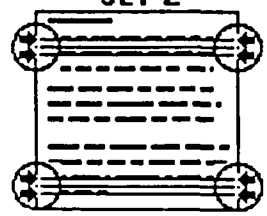
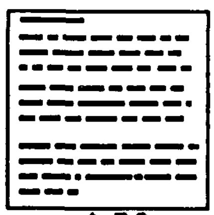
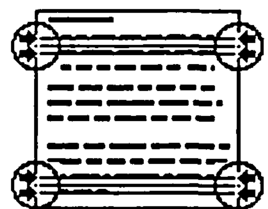
	SET 1	SET 2
ICON		
MIXED	 ^ BL	 BEGI LN
TEXT	^ BL	BEGI LN

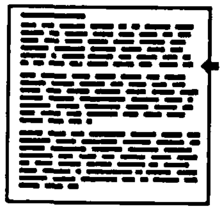
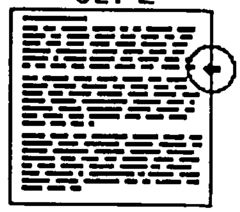
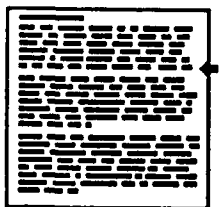
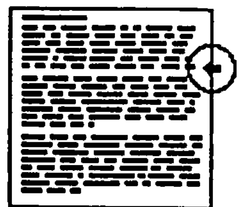
	SET 1	SET 2
ICON		
MIXED	 ^ BT	 BEGI TXT
TEXT	^ BT	BEGI TXT

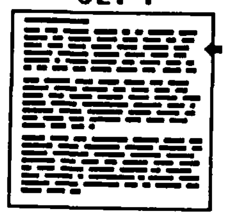
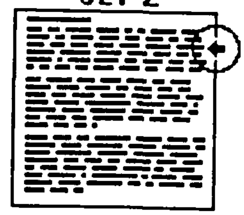
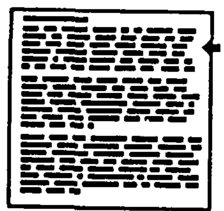
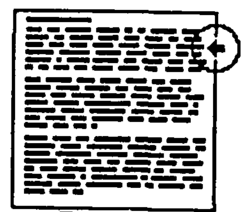
	SET 1	SET 2
ICON		
MIXED	 ^ DL	 DELE LN
TEXT	^ DL	DELE LN

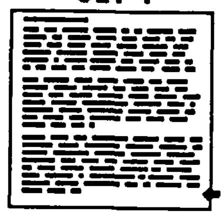
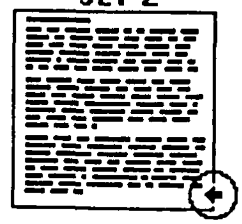
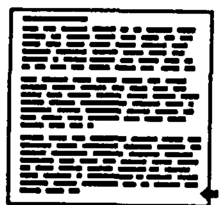
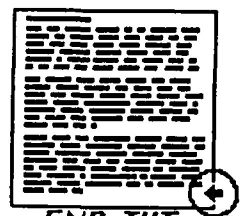
	SET 1	SET 2
ICON		
MIXED	 ^ DP	 DELE PARA
TEXT	^ DP	DELE PARA

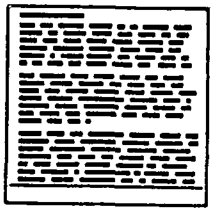
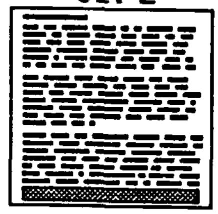
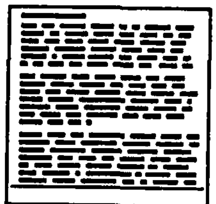
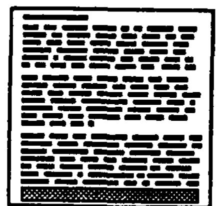
	SET 1	SET 2
ICON		
MIXED	 ^ DW	 DELE WRD
TEXT	^ DW	DELE WRD

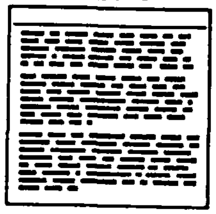
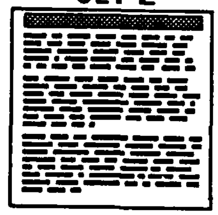
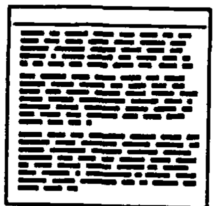
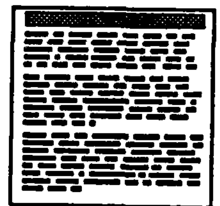
	SET 1	SET 2
ICON		
MIXED	 ^ DS	 DOUB SPC
TEXT	^ DS	DOUB SPC

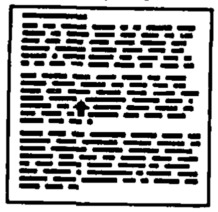
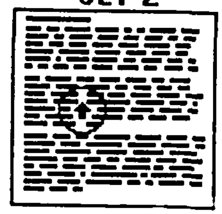
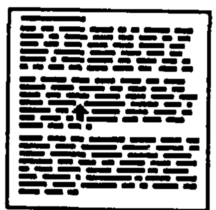
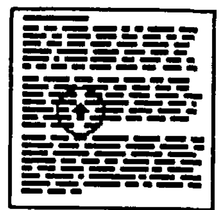
	SET 1	SET 2
ICON		
MIXED	 ^ EB	 END BLCK
TEXT	^ EB	END BLCK

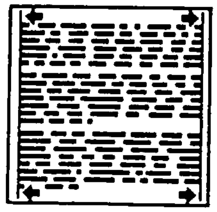
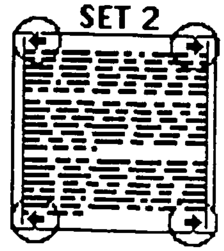
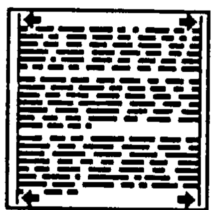
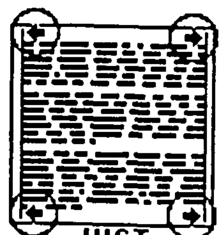
	SET 1	SET 2
ICON		
MIXED	 ^ EL	 END LN
TEXT	^ EL	END LN

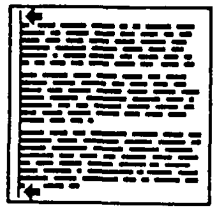
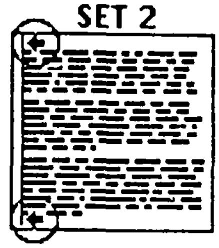
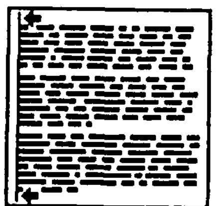
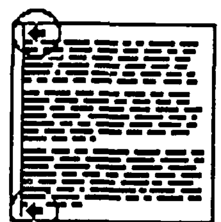
	SET 1	SET 2
ICON		
MIXED	 ^ ET	 END TXT
TEXT	^ ET	END TXT

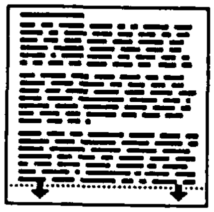
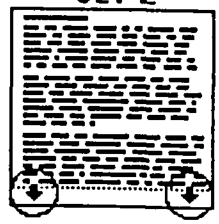
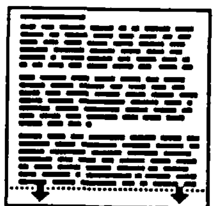
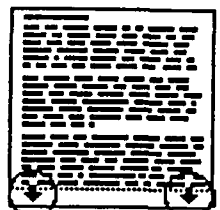
	SET 1	SET 2
ICON		
MIXED	 ^ F	 FOOT
TEXT	^ F	FOOT

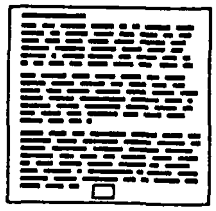
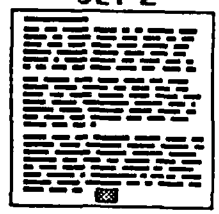
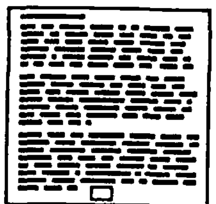
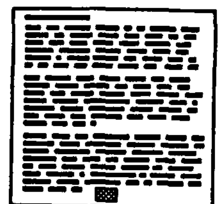
	SET 1	SET 2
ICON		
MIXED	 ^ H	 HEAD
TEXT	^ H	HEAD

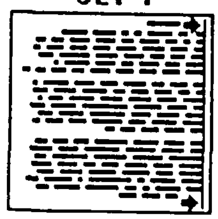
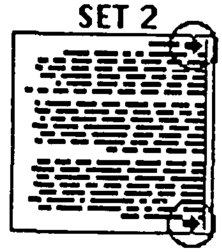
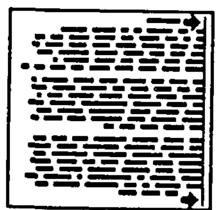
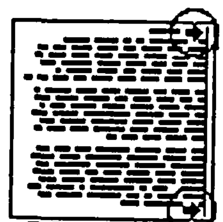
	SET 1	SET 2
ICON		
MIXED	 ^ IW	 INSE
TEXT	^ IW	INSE

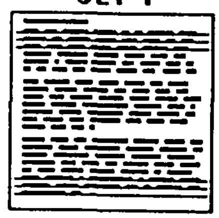
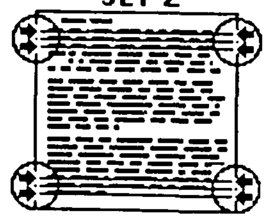
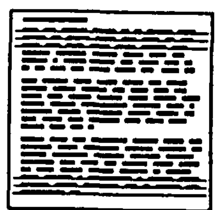
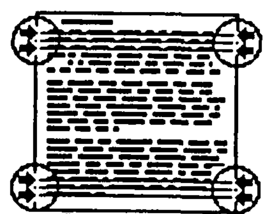
ICON	SET 1 	SET 2 
MIXED	 ^ J	 JUST
TEXT	^ J	JUST

	SET 1	SET 2
ICON		
MIXED	 ^ LJ	 LEFT JUST
TEXT	^ LJ	LEFT JUST

	SET 1	SET 2
ICON		
MIXED	 ^ PB	 PAGE BRK
TEXT	^ PB	PAGE BRK

	SET 1	SET 2
ICON		
MIXED	 ^ P	 PAGI
TEXT	^ P	PAGI

	SET 1	SET 2
ICON		
MIXED	 ^ RJ	 RGHT JUST
TEXT	^ RJ	RGHT JUST

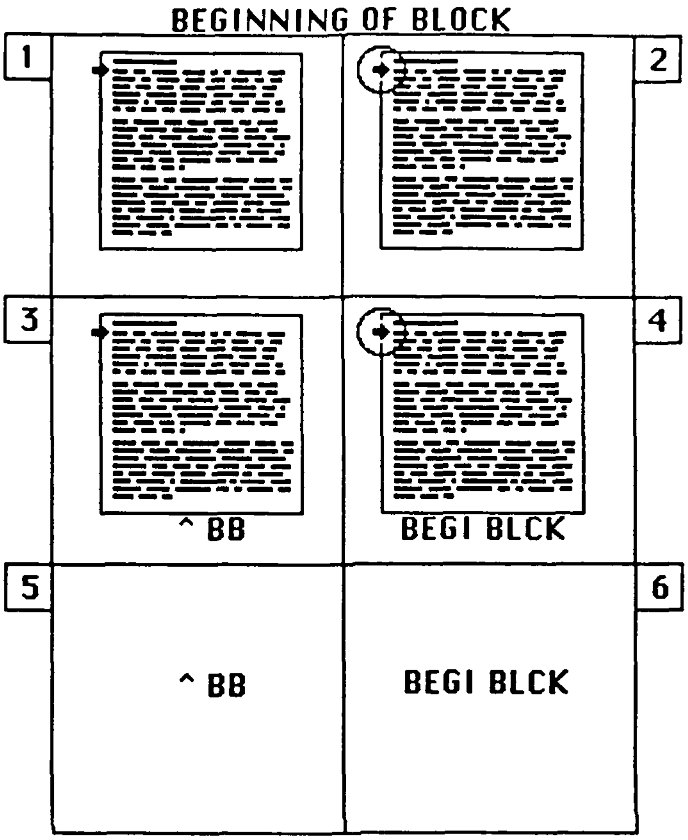
	SET 1	SET 2
ICON		
MIXED	 ^ SS	 SING SPC
TEXT	^ SS	SING SPC

APPENDIX F
Preference Survey
Form

The organization of the preference survey forms follows the alphabetical arrangement used in Appendix E. Each sheet contains the designation label as utilized in the acquisition task.

As with Appendix E, the following index is provided in an attempt to make transitioning through the document more convenient.

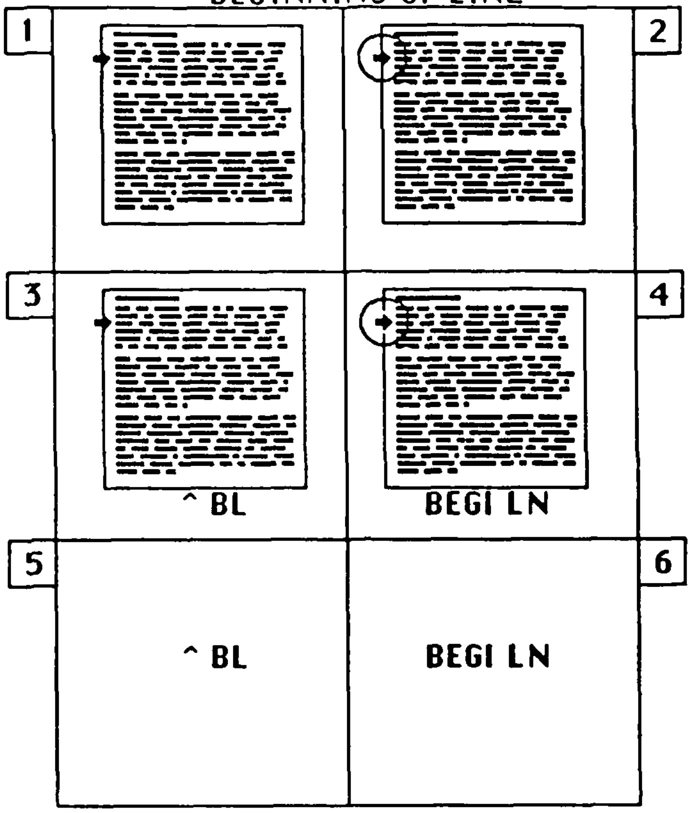
INDEX



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____
____
____
____
____
Least ____

BEGINNING OF LINE



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

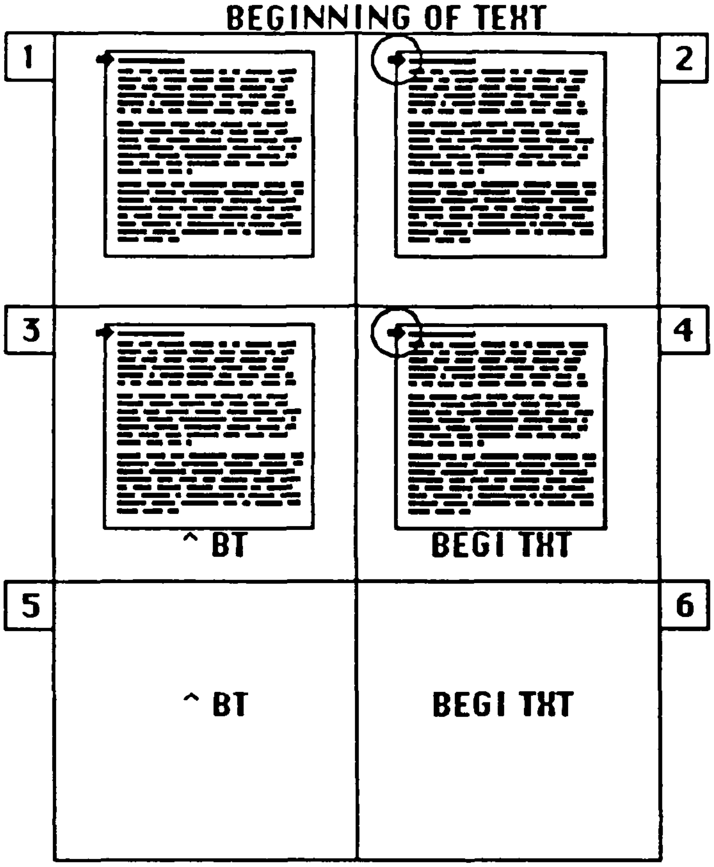
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

_____

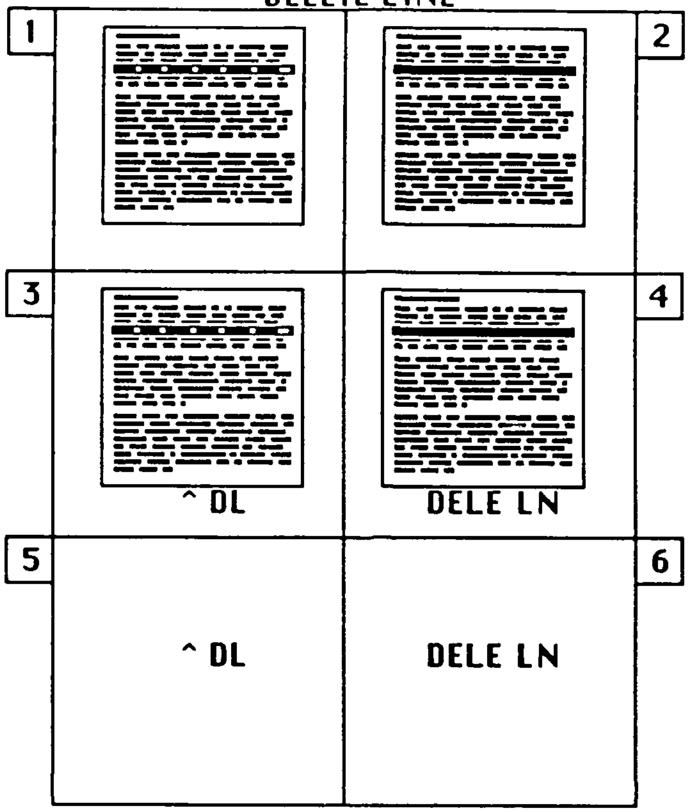
_____

_____

_____

Least _____

DELETE LINE



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

____

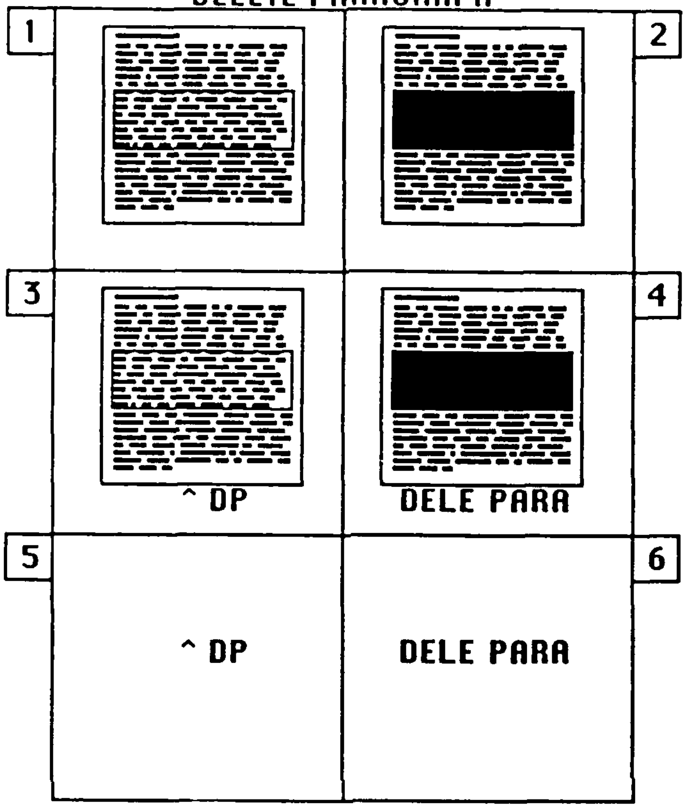
____

____

____

Least ____

DELETE PARAGRAPH



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

____

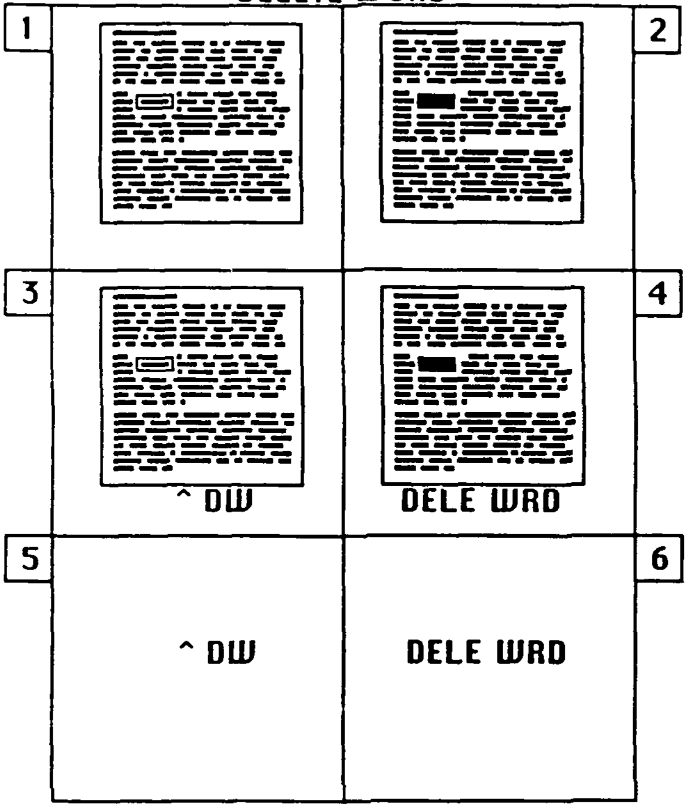
____

____

____

Least ____

DELETE WORD



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

____

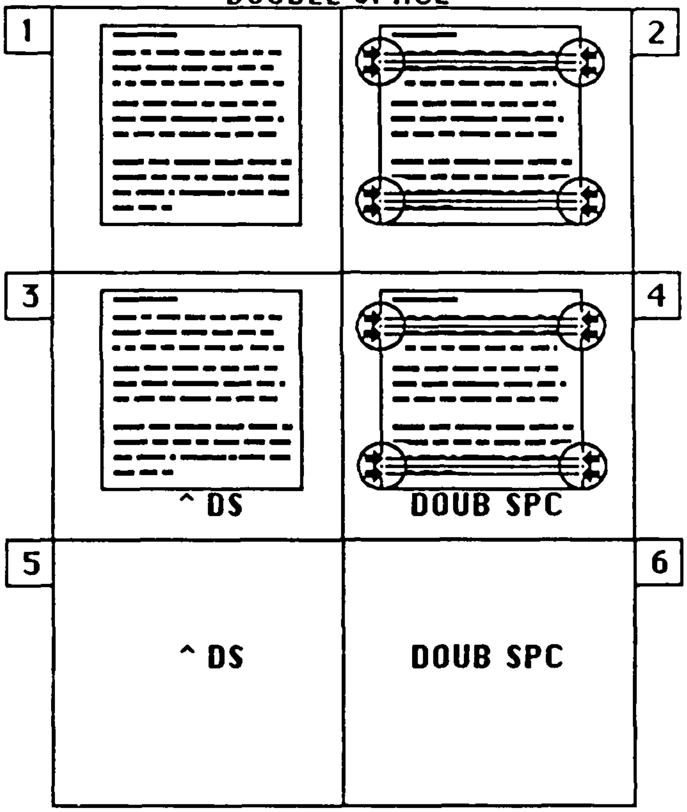
____

____

____

Least ____

DOUBLE SPACE



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

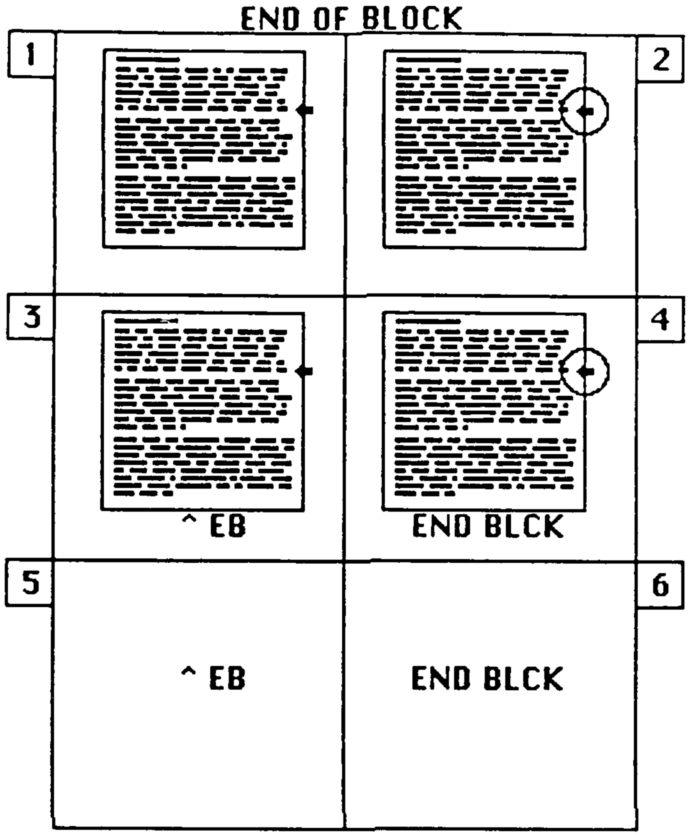
____

____

____

____

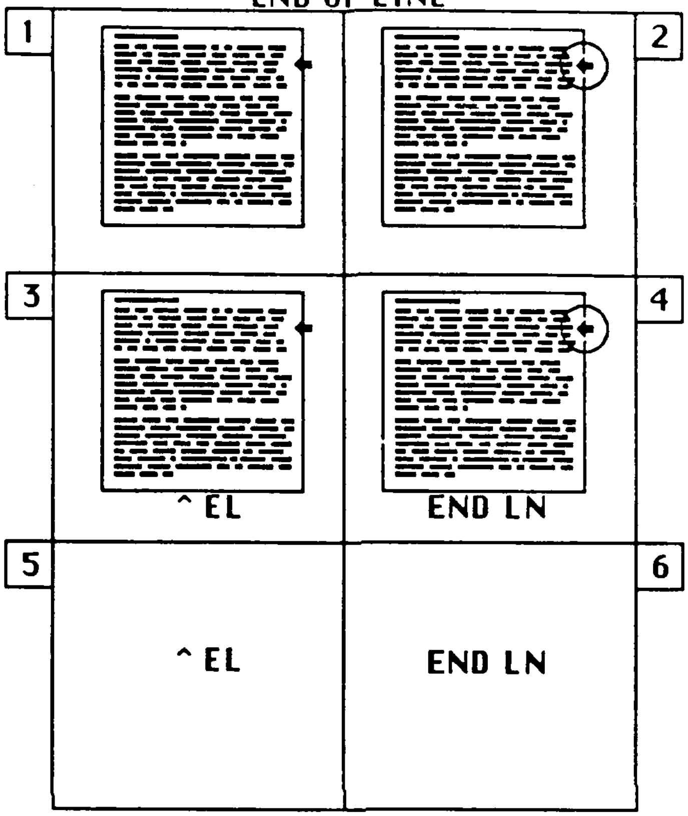
Least ____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____
____
____
____
____
Least ____

END OF LINE



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

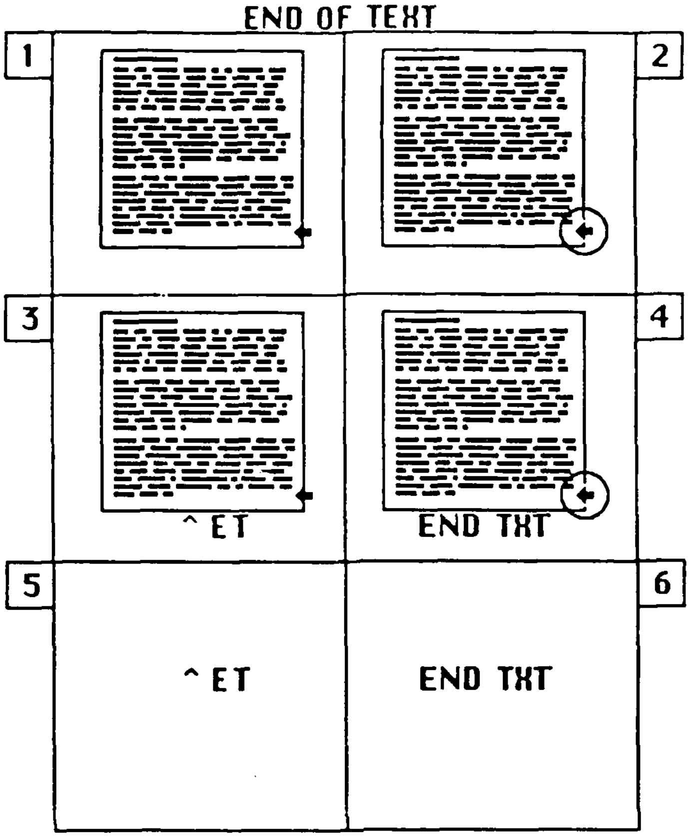
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

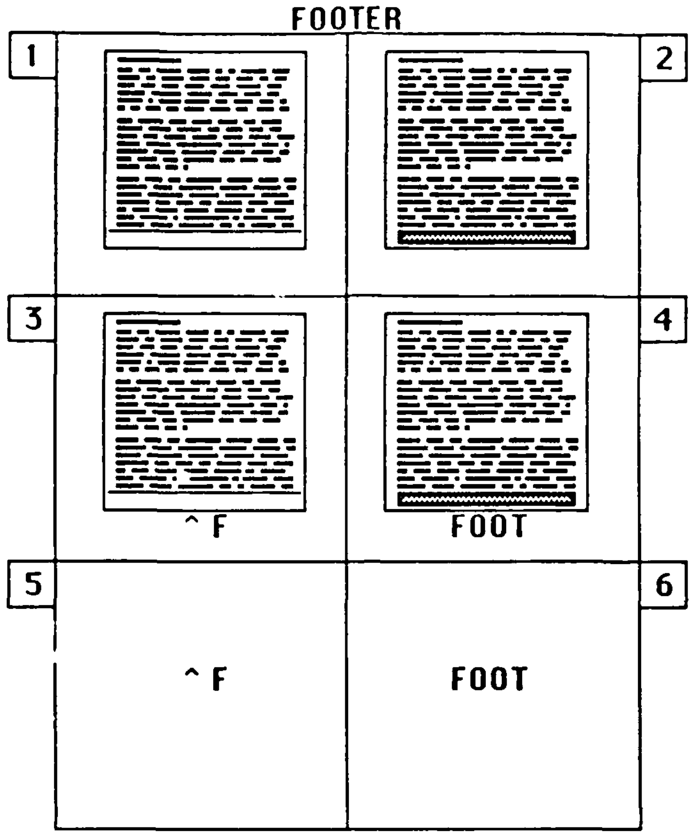
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

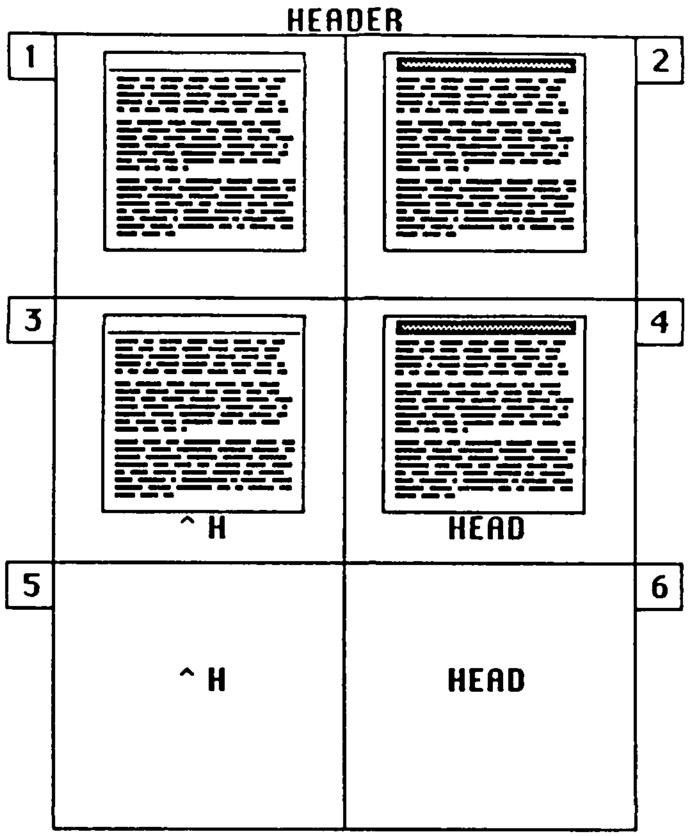
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

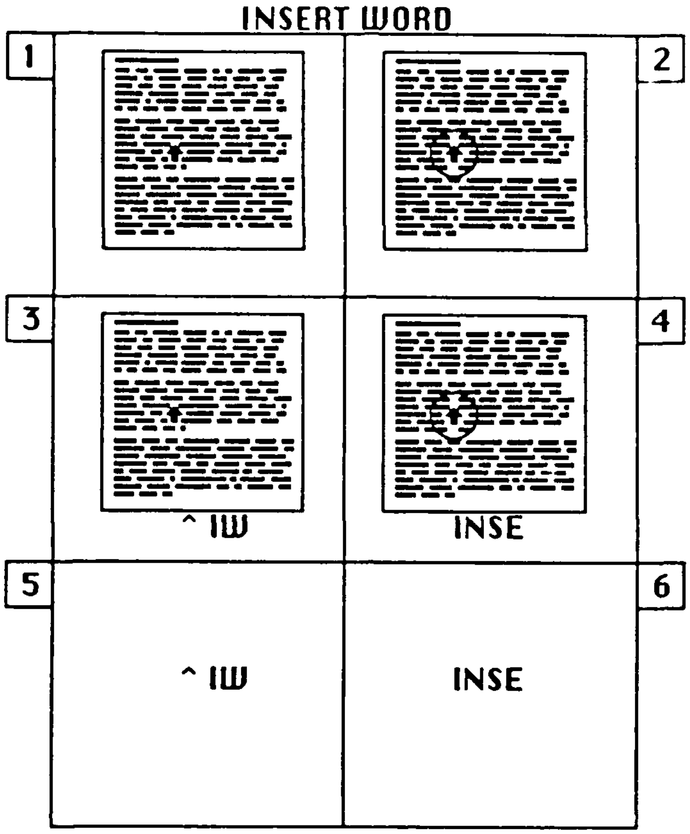
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

____

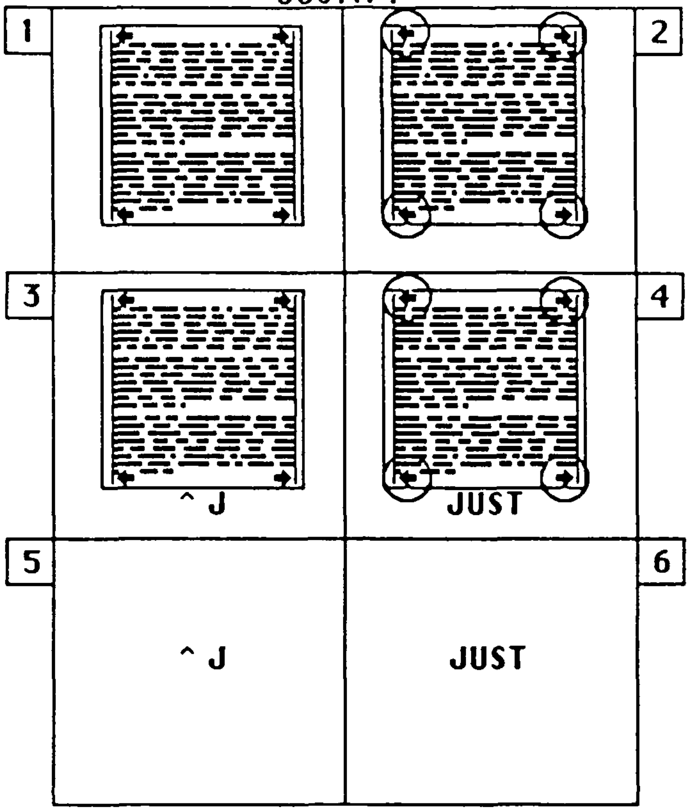
____

____

____

Least ____

JUSTIFY



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

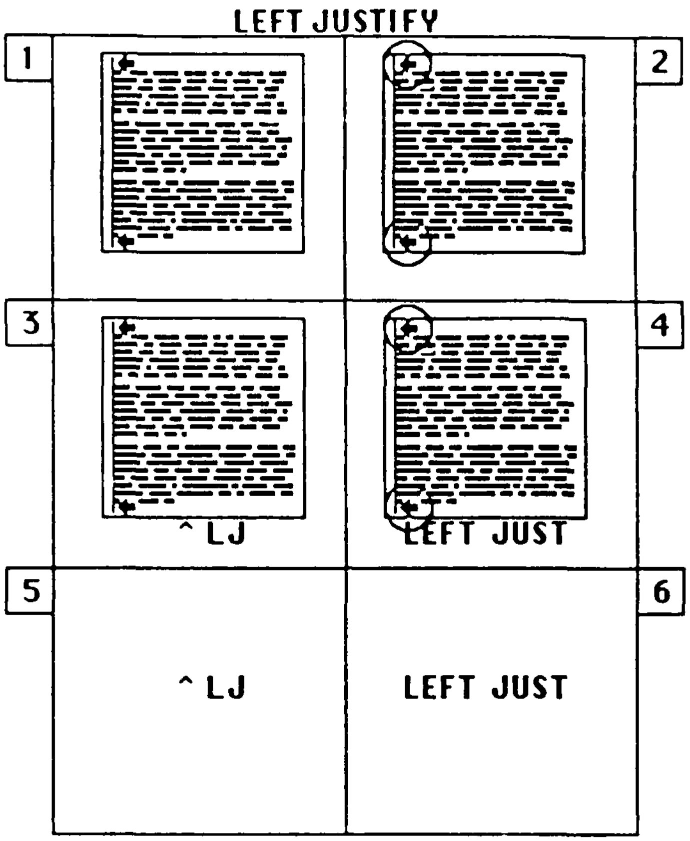
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

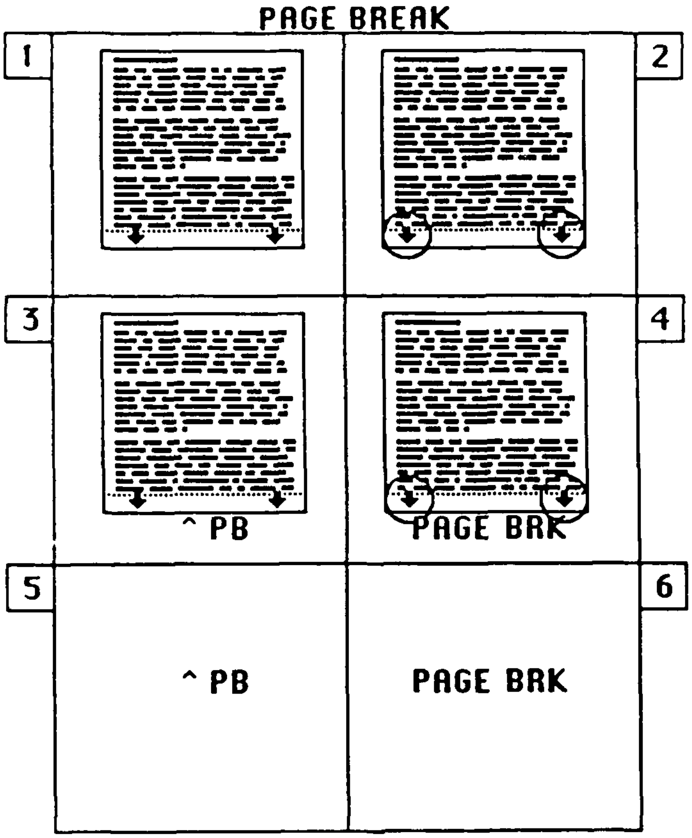
____

____

____

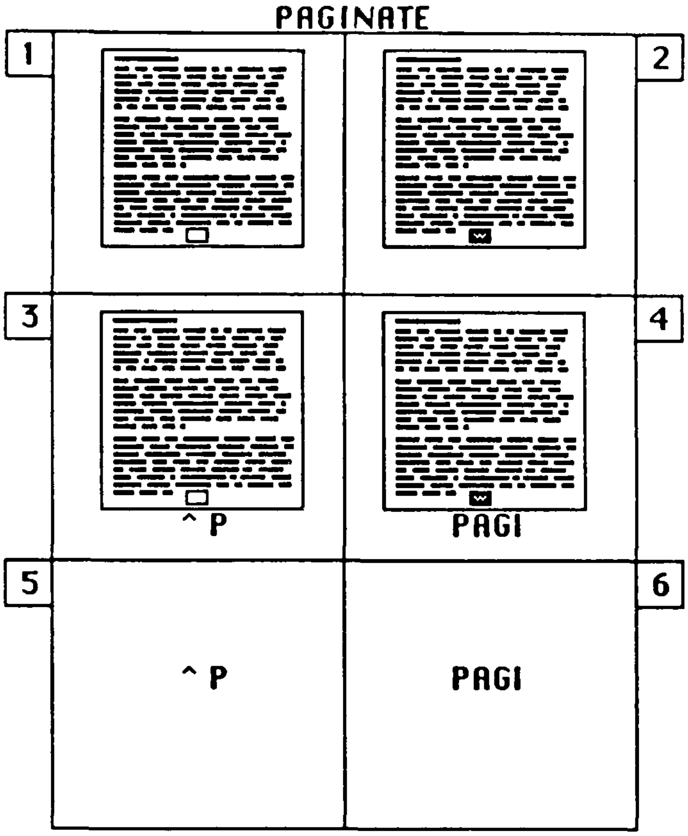
____

Least ____



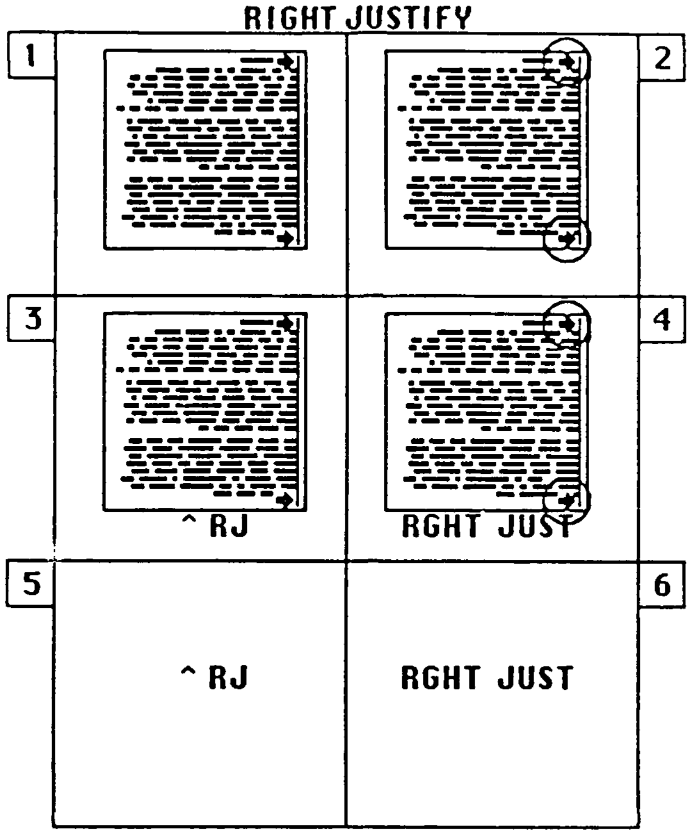
Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____
____
____
____
____
Least ____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____
____
____
____
____
Least ____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most _____

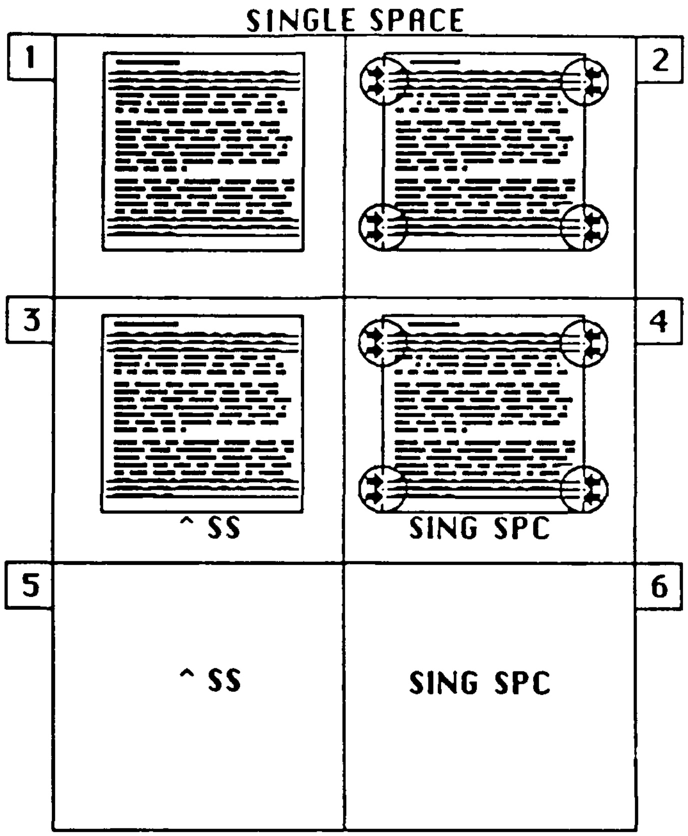
_____

_____

_____

_____

Least _____



Please indicate your preference for each representation by placing the corresponding number in the appropriate line below.

Most ____

____

____

____

____

Least ____

APPENDIX G
Computer Program
Listing

```
DIM INSTAR$(100),STIMAR$(250),RANDAR(250)
CALL TEXTFONT (4):CALL TEXTSIZE(9)
CALL TEXTFONT (211):CALL TEXTSIZE(12)
CALL TEXTFONT (3):CALL TEXTSIZE(9)
CALL TEXTFONT (211):CALL TEXTSIZE(12)
CALL TEXTFONT (3):CALL TEXTSIZE(9)
CALL TEXTFONT (4):CALL TEXTSIZE(9)
resp=1:x=1:y=1:REC=0
St$=STRING$(90,45)
WINDOW 1," XXX ",(0,20)-(511,639),3
MENU 1,0,1,"
"
BREAK ON
ON BREAK GOSUB finish
RANDOMIZE TIMER
AGAIN:
    M= INT(100*RND(1))
    IF M <1 OR M>15 THEN GOTO AGAIN
    OPEN "RNDNUM"+STR$(M) FOR INPUT AS #1
    FOR i=1 TO 114
    INPUT #1,x
    RANDAR(i)=x
    NEXT
CLOSE #1

OPEN "DATA DEMOFILE2" FOR INPUT AS #1
    FOR L=1 TO 46
    INPUT #1, x$
    INSTAR$(L)=x$
    NEXT
CLOSE #1

OPEN "STIMULI FILE" FOR INPUT AS #1
    FOR i=1 TO 114
    INPUT #1, x$
    STIMAR$(i)=x$
    NEXT
CLOSE #1

SECRND:
    N= INT(100*RND(1))
    IF N <1 OR N>15 THEN GOTO SECRND
OPEN "RNDNUM"+STR$(N) FOR INPUT AS #1
    FOR i=115 TO 228
    INPUT #1,x
    RANDAR(i)=x
    NEXT
CLOSE #1

CLS
START:
```

```
    CALL TEXTFONT (0):CALL TEXTSIZE (12)
    LOCATE 5,20:INPUT"Enter Number for Subject  'XXXX' ",s
    CLS
SEX:
    CLS
    LOCATE 5,20:PRINT"Select Sex"
    BUTTON 1,1,"Male",(200,80)-(370,110),3
    BUTTON 2,1,"Female",(200,105)-(300,135),3
    WHILE DIALOG (0) <> 1:WEND
    IF DIALOG (1) = 1 THEN SS=1
    IF DIALOG (1) = 2 THEN SS=2
    BUTTON CLOSE 1
    BUTTON CLOSE 2

AGE:
    CLS
    LOCATE 5,20:PRINT"Select Age Category"
    BUTTON 1,1,"16 - 25 years old",(200,80)-(370,110),3
    BUTTON 2,1,"26 - 35 ",(200,105)-(300,135),3
    BUTTON 3,1,"36 - 45 ",(200,130)-(300,160),3
    BUTTON 4,1,"46 - 55 ",(200,155)-(370,185),3
    BUTTON 5,1,"56 - 65 ",(200,180)-(300,210),3
    WHILE DIALOG (0) <> 1:WEND
    IF DIALOG (1) = 1 THEN SA=1
    IF DIALOG (1) = 2 THEN SA=2
    IF DIALOG (1) = 3 THEN SA=3
    IF DIALOG (1) = 4 THEN SA=4
    IF DIALOG (1) = 5 THEN SA=5
    BUTTON CLOSE 1
    BUTTON CLOSE 2
    BUTTON CLOSE 3
    BUTTON CLOSE 4
    BUTTON CLOSE 5

EXPER:
    CLS
    LOCATE 5,20:PRINT "Select Mode "
    BUTTON 1,1,"1",(200,80)-(370,110),3
    BUTTON 2,1,"2",(200,105)-(300,135),3
    BUTTON 3,1,"3",(200,130)-(300,160),3
    WHILE DIALOG (0) <> 1:WEND
    IF DIALOG (1) = 1 THEN SXP=1
    IF DIALOG (1) = 2 THEN SXP=2
    IF DIALOG (1) = 3 THEN SXP=3
    BUTTON CLOSE 1
    BUTTON CLOSE 2
    BUTTON CLOSE 3

CLS:CALL TEXTFONT (0):CALL TEXTSIZE(12)
LOCATE 5,20:PRINT"Please Make Selection"
BUTTON 1,1,"Acquisition",(200,80)-(370,110),3
```

```
BUTTON 2,1,"Recall",(200,105)-(300,135),3
BUTTON 3,1,"Quit",(200,130)-(300,160),3
B$="###.##"
resp=1:x=1:y=1:REC=0
WHILE DIALOG (0) <> 1:WEND
IF DIALOG (1) = 1 THEN
msg$="Acquisition":TRIAL=0:mde=1:CLS:GOSUB SHUTBUT:GOSUB
PRTHEA
IF DIALOG (1) = 2 THEN msg$="Recall":mde=3:GOSUB
SHUTBUT:CLS:GOSUB PRTHEAD:TRIAL=235:x=37:GOSUB out:GOTO
readvalue
IF DIALOG (1) = 3 THEN GOTO QUIT
BUTTON CLOSE 1
BUTTON CLOSE 2
BUTTON CLOSE 3
    OPEN "SUBJECTDATA"+STR$(s) AS #3 LEN= 64
    FIELD #3, 8 AS ZREC$, 4 AS ZS$, 4 AS ZMDE$,4 AS ZSXP$, 4
AS ZSS$, 4 AS ZSA$, 4 AS ZTRIAL$, 4 AS ZFT$, 4 AS ZSETBL$, 4
AS ZNUM$, 8 AS ZTRIALT$,8 AS ZELAPSED$,4 AS ZRESP$

readvalue:
    NUM$=INSTAR$(x):form$=NUM$
    NUM$=MID$(NUM$,1,2):NUM=VAL(NUM$)
    form=VAL(MID$(form$,3,1))
    IF form=1 THEN FID=200:FSZ=127:GOSUB DOUBLE
    IF form=6 THEN FID=201:FSZ=127:GOSUB DOUBLE
    IF form=2 THEN FID=4:FSZ=9:GOSUB SINGLE
    IF form=7 THEN FID=215:FSZ=72:FT=0:GOSUB PRACTICE
    IF mde=3 AND x=45 THEN y=1:GOTO stimu
    IF x=36 AND y=114 THEN mde=2:y=115:GOTO stimu
    IF x=33 AND y=1 THEN LPRINT St$:LPRINT
DATE$;TAB(25);TIME$;:LPRINT St$:x=34:GOTO stimu
    x=x+1
GOTO readvalue

stimu:
    NUM$=STIMAR$(RANDAR(y)):form$=NUM$
    NUM$=MID$(NUM$,1,2):NUM=VAL(NUM$)
    form=VAL(MID$(form$,3,1))
    IF NUM > 66 THEN num2= (NUM-32) ELSE num2=NUM
    IF NUM > 66 THEN SETBL=2 ELSE SETBL=1
    IF form=3 THEN FT= 1:GOSUB ICON
    IF form=4 THEN FT= 2:GOSUB TEXT
    IF form=5 THEN FT= 3:GOSUB TRIPLE
    IF y = 114 AND mde=1 THEN x=34:LPRINT St$:LPRINT
DATE$;TAB(25);TIME$:LPRINT "       Random Series = ";N:LPRINT
St$:GOSUB readvalue
    IF y = 228 THEN LPRINT St$:LPRINT
DATE$;TAB(25);TIME$:LPRINT St$:GOSUB finish
```

```
    IF y = 114 AND mde=3 THEN LPRINT St$:LPRINT
DATE$;TAB(25);TIME$:LPRINT
St$:x=99:FID=201:FSZ=127:NUM=58:GOSUB DOUBLE
    y=y+1
GOTO stimu
STOP


DOUBLE:
    CLS
    CALL TEXTFONT (FID):CALL TEXTSIZE (FSZ):CALL TEXTMODE(1)
    LOCATE 1,1:PRINT PTAB(150);CHR$(NUM)
    CALL TEXTFONT (FID):CALL TEXTSIZE (FSZ):CALL TEXTMODE(1)
    LOCATE 2,1:PRINT PTAB(150);CHR$(NUM+1):GOSUB pause
    BUTTON 1,1,"NEXT",(180,275)-(330,310)
    IF x=1 THEN CALL TEXTFONT(0):CALL TEXTSIZE(12):CALL
TEXTMODE(0):CALL TEXTFACE(0):LOCATE 18,11:PRINT "'NEXT":CALL
TEXTFACE(0)
    IF x=1 THEN CALL TEXTFONT(0):CALL TEXTSIZE(12):CALL
TEXTMODE(0):CALL TEXTFACE(0):LOCATE 19,10:PRINT "BUTTON' -
>":CALL TEXTFACE(0)
    IF x =99 AND mde=3 THEN GOSUB pause:GOSUB
pause:CLOSE:MENU RESET:END
    WHILE DIALOG (0) <> 1:WEND
    IF DIALOG (1) = 1 THEN BUTTON CLOSE 1:RETURN

PRACTICE:
    CLS:REC=REC+1
    CALL TEXTFONT (215):CALL TEXTSIZE (72):CALL TEXTMODE(1)
    LOCATE 2,3:PRINT PTAB(200); CHR$(NUM)
    IF mde=3 THEN GOTO skipprac
    CALL TEXTFONT (215):CALL TEXTSIZE (72):CALL TEXTMODE(1)
    LOCATE 3,3:PRINT PTAB(200); CHR$(NUM+16)
    skipprac:
    IF mde <=2 AND x=25 THEN CALL TEXTFONT(0):CALL
TEXTSIZE(12):CALL TEXTMODE(0):CALL TEXTFACE(0):LOCATE
8,6:PRINT "'REPRESENTATION' ->":CALL TEXTFACE(0)
    IF mde <=2 AND x=25 THEN CALL TEXTFONT(0):CALL
TEXTSIZE(12):CALL TEXTMODE(0):CALL TEXTFACE(0):LOCATE
12,12:PRINT "'DESIGNATION' ->":CALL TEXTFACE(0)
    BUTTON 4 ,1,"I Got It!!",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND
    TRIALT=elapsed:elapsed=0
    BUTTON CLOSE 4
    BEEP
    CLS
    BUTTON 4,1,"Ready",(180,270)-(330,310)
```

```
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND:GOSUB PSRT:BUTTON CLOSE 4:GOSUB pause:RETURN


SINGLE:
    CALL TEXTFONT (4):CALL TEXTSIZE (9):CALL TEXTMODE (1)
    CLS
    LOCATE 9,2:PRINT PTAB(190); CHR$(NUM)
    BUTTON 1,1,"NEXT",(180,275)-(330,310)
    WHILE DIALOG (0) <> 1:WEND
    IF DIALOG (1) = 1 THEN BUTTON CLOSE 1:RETURN

TRIPLE:
    CLS:REC=REC+1
    CALL TEXTFONT (3):CALL TEXTSIZE (9):CALL TEXTMODE(1)
    LOCATE 2,2:PRINT PTAB(205);CHR$(NUM)
    CALL TEXTFONT (211):CALL TEXTSIZE (12):CALL TEXTMODE(1)
    LOCATE 12,50:PRINT PTAB(220);CHR$(NUM)
    IF mde>=2 THEN GOTO TRIPSKIP
    CALL TEXTFONT (4):CALL TEXTSIZE (9):CALL TEXTMODE(1)
    LOCATE 15,3:PRINT PTAB(190);CHR$(num2)
TRIPSKIP:
    BUTTON 4 ,1,"I Got It!!",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND
    TRIAL=TRIAL+1
    TRIALT=elapsed:elapsed=0
    BUTTON CLOSE 4
    BEEP
    CLS
    BUTTON 4,1,"Ready",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND:GOSUB PSRT:BUTTON CLOSE 4:GOSUB pause:RETURN

ICON:
    CLS:REC=REC+1
    CALL TEXTFONT (3):CALL TEXTSIZE (9):CALL TEXTMODE(1)
    LOCATE 2,2:PRINT PTAB(205);CHR$(NUM)
    IF mde=>2 THEN GOTO ICONSKIP
    CALL TEXTFONT (4):CALL TEXTSIZE (9):CALL TEXTMODE(1)
    LOCATE 14,3:PRINT PTAB(190);CHR$(num2)
ICONSKIP:
```

```
    BUTTON 4 ,1,"I Got It!!",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND
    TRIAL=TRIAL+1
    TRIALT=elapsed:elapsed=0
    BUTTON CLOSE 4
    BEEP
    CLS
    BUTTON 4,1,"Ready",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND:GOSUB PSRT:BUTTON CLOSE 4:GOSUB pause:RETURN

TEXT:
    CLS:REC=REC+1
    CALL TEXTFONT (211):CALL TEXTSIZE (12):CALL TEXTMODE(1)
    LOCATE 11,50:PRINT PTAB(220);CHR$(NUM)
    CALL TEXTFONT (4):CALL TEXTSIZE (9):CALL TEXTMODE(1)
    IF mde=>2 THEN GOTO TEXTSKIP
    LOCATE 14,3:PRINT PTAB(190);CHR$(num2)
TEXTSKIP:
    BUTTON 4 ,1,"I Got It!!",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND
    TRIAL=TRIAL+1
    TRIALT=elapsed:elapsed=0
    BUTTON CLOSE 4
    BEEP
    CLS
    BUTTON 4,1,"Ready",(180,270)-(330,310)
    GOSUB TIMEIN
    WHILE DIALOG (0) <> 1:G = PEEK(365):F = PEEK(364):E =
PEEK(363):EPKSEC=F*255/60+G/60+E*255*255/60:elapsed=EPKSEC-
SPKSEC:elapsed=elapsed*100:elapsed=INT(elapsed):elapsed=elaps
ed/100:WEND:GOSUB PSRT:BUTTON CLOSE 4:GOSUB pause:RETURN


SHUTBUT:
    BUTTON CLOSE 1
    BUTTON CLOSE 2
    BUTTON CLOSE 3
    BUTTON CLOSE 4
    RETURN
```

```
out:
    OPEN "RECALLDATA"+STR$(s) AS #3 LEN= 64
    FIELD #3, 8 AS ZREC$, 4 AS ZS$, 4 AS ZMDE$,4 AS ZSXP$, 4
AS ZSS$, 4 AS ZSA$, 4 AS ZTRIAL$, 4 AS ZFT$, 4 AS ZSETBL$, 4
AS ZNUM$, 8 AS ZTRIALT$,8 AS ZELAPSED$,4 AS ZRESP$
    RETURN

TIMEIN:
        SE = PEEK(363)
        SF = PEEK(364)
        SG = PEEK(365)
        SPKSEC=SF*255/60+SG/60+SE*255*255/60
RETURN

TIMEOUT:
        G = PEEK(365)
        F = PEEK(364)
        E = PEEK(363)
        EPKSEC=F*255/60+G/60+E*255*255/60
        elapsed=EPKSEC-SPKSEC
        elapsed = elapsed * 100:elapsed =
INT(elapsed):elapsed = elapsed/100
        RETURN

PRTHEAD:
    LPRINT CHR$(12)
    LPRINT St$
    LPRINT "Subject Number for session= ", s, DATE$,TIME$
    LPRINT TAB(10);"Mode = ";mde; TAB(15);" Experience= ";
SXP;TAB(35);" Sex= ";SS; TAB(45);"Age= ";SA;TAB(53);"Series =
";M
    LPRINT St$
    LPRINT TAB(10); "Rec";"  Sub #";"  Mode";" Exp"; "
Sex";"  Age";" Trial";" Form ";" Setbl ";" Char";"  RespT  ";
"   Rest ";"  Resp"
    LPRINT St$
RETURN

PSRT:

    LSET ZREC$=MKD$(REC)
    LSET ZS$=MKS$(s)
    RSET ZMDE$=MKS$(mde)
    RSET ZSXP$ = MKS$(SXP)
    RSET ZSS$=MKS$(SS)
    LSET ZSA$=MKS$(SA)
    RSET ZTRIAL$=MKS$(TRIAL)
    RSET ZFT$=MKS$(FT)
    RSET ZSETBL$=MKS$(SETBL)
    RSET ZNUM$=MKS$(NUM)
    RSET ZTRIALT$=MKD$(TRIALT)
```

```
    RSET ZELAPSED$=MKD$(elapsed)
    RSET ZRESP$=MKS$(resp)
    PUT #3,REC

    LPRINT TAB(10);REC;TAB(18);s;TAB(24);mde;TAB (28);SXP;
TAB (33);SS;TAB (37);
SA;TAB(42);TRIAL;TAB(49);FT;TAB(55);SETBL;TAB(60)NUM;TAB(65);
:LPRINT USING B$;TRIALT;:LPRINT TAB(75);:LPRINT USING
B$;elapsed;:LPRINT TAB(85);resp
    elapsed=0
    RETURN


pause:
FOR i = 1 TO 5000:NEXT
RETURN

Finish:
    CLS
    CALL TEXTFONT (0):CALL TEXTSIZE (12)
    LOCATE 10,20:PRINT "This completes this session....."
    LOCATE 11,20 :PRINT "Thank you for your participation."
    GOSUB pause:GOSUB pause
    MENU RESET
    CLOSE#3
END
```